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# Third National Assessment of Environmental Effects Monitoring Information from Metal Mines Subject to the *Metal Mining Effluent Regulations*

Industrial Sectors, Chemicals and Waste and Environmental Protection Operations Directorates, Environment and Climate Change Canada

**December 2015**

Canada

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## Synopsis

Metal mines in Canada are required to conduct environmental effects monitoring (EEM) studies of the potential effects of mine effluent on the aquatic environment as a condition governing their authority to deposit effluent under the *Metal Mining Effluent Regulations* (MMER) pursuant to the *Fisheries Act*. The results of EEM studies conducted by regulated mines represent an important source of information for assessing the adequacy of the regulations for protecting the aquatic environment. Although the metal mining sector is achieving over 95% compliance with the prescribed limits (Environment Canada 2015), a decade of EEM results has shown that impacts do occur on fish and fish habitat downstream from metal mines, but rarely do effluents impact the consumption of fish by humans.

In the MMER, an “effect” is defined as a statistical difference between specific data collected from an area exposed to mine effluent and data collected from a similar reference area that is not exposed to mine effluent. The presence or absence of an effect is considered “confirmed” when a similar type of effect or the absence of an effect has been observed in two consecutive studies.

Eighty-two mines have completed at least two consecutive studies to assess the effects of mine effluent. Of these mines, 76% (62/82) confirmed the presence of effects on fish or fish habitat, or both. Ninety-two percent (57/62) of mines that confirmed effects observed at least one effect of a magnitude that may be indicative of a higher risk to the environment. One mine confirmed the absence of effects on fish, fish habitat and the use of fisheries resources. The presence or absence of effects remained unconfirmed for 23% (19/82) of mines that completed two or more studies, because the results of these studies were variable (an effect observed in one study, but a similar type of effect not observed in the second study).

The types of effects identified by this third national assessment were similar to those identified by the previous national assessments. Fish in the exposure area were thinner or fatter, older or younger and had smaller or larger livers and gonads than fish in the reference area. Fish habitats exposed to effluent had experienced a change in benthic invertebrate community structure, contained more or fewer individuals and had fewer species present.

When the presence of effects was confirmed, mines were required to conduct sampling in additional locations within the exposure area to assess the magnitude and geographic extent (M&E) of these effects. Most mines (25/29 or 86%) that assessed the M&E of confirmed effects observed one or more of the same effects within the exposure area farther from the point of effluent discharge. To date, effluent from current mining activities has been shown to cause or contribute to effects in 77% (20/26) of studies completed to determine the causes of effects. The effluent substances associated with effects were major ions, metals, nitrogen, total suspended solids, phosphorus and selenium.

## Executive Summary

The *Metal Mining Effluent Regulations* (MMER) came into force in 2002 under the *Fisheries Act*. They prescribe end-of-pipe (discharge) limits for specified substances, and provide a national standard that is intended to protect fish, fish habitat and the use of fisheries resources. The metal mining sector is achieving over 95% compliance with the prescribed discharge limits and meeting the requirement that effluent not be acutely lethal to rainbow trout (Environment Canada 2015). In addition to complying with end-of-pipe limits, Canadian mines subject to the MMER are required to conduct environmental effects monitoring (EEM) studies of the potential effects of mine effluent on the aquatic environment. Information obtained through EEM supports the evaluation of the effectiveness of the Regulations in protecting the aquatic environment and of current and future pollution prevention and control technologies, practices and programs within the mining sector. The purpose of this report is to present the main findings of the EEM studies conducted by mines across Canada.

The EEM studies required by the MMER consist of biological, effluent and water quality monitoring studies. Biological monitoring studies are conducted on three components: fish populations, fish habitat (represented by the benthic invertebrate community) and the use of fisheries resources by humans (represented by mercury concentrations in fish tissue). Effluent and water quality monitoring studies, consisting of chemical characterization and sublethal toxicity (SLT) testing of final effluent and water quality monitoring in the environment, contribute to the assessment of effluent quality and aquatic environment conditions at individual mine sites. This report focuses on the biological components of EEM studies in order to provide a national assessment of the potential effects of metal mining effluents on aquatic environments.

The third national assessment report summarizes the biological monitoring studies undertaken to assess the presence or absence of effects that were submitted to Environment and Climate Change Canada (ECCC) before October 1, 2013 and the biological monitoring studies conducted to investigate the magnitude, geographic extent and cause of observed effects that were submitted before June 2014. The results of the SLT and effluent characterization studies that were carried out from 2003 to 2012 are also summarized in order to provide supporting information.

In the MMER, an “effect” is defined as a statistical difference between specific data collected from an area exposed to mine effluent and from a similar reference area not exposed to mine effluent. There are five effect indicators associated with the fish population component, four effect indicators associated with the fish habitat component and one criterion associated with an effect on the use of fisheries resources. The presence or absence of an effect is considered “confirmed” when a similar type of effect or the absence of an effect has been observed in two consecutive studies. If effects are observed in one study and different effects or no effects are observed in the second study, the presence or absence of effects is considered “unconfirmed” and further studies are required to obtain confirmation.

Although the metal mining sector is achieving over 95% compliance with the prescribed discharge limits, a decade of EEM results have shown that impacts do occur on fish and fish habitat downstream from metal mines, but rarely do effluents impact the consumption of fish by humans.

Most mines (62/82 or 76%) that have completed two consecutive studies to assess effects confirmed at least one effect, and 52% (32/62) of these mines confirmed effects on both fish and fish habitat. One mine confirmed the absence of effects on fish, fish habitat and the use of fisheries resources. Almost all mines (57/62 or 92%) with confirmed effects observed at least one effect of a magnitude that may be indicative of a higher risk[1] to the environment.

For fish, changes (increases and decreases) in the relationship between body weight and length, known as body condition, were the most prevalent effect observed, but changes in survival, growth, reproduction and liver condition were also observed. Survival, growth and liver condition indicators were more often larger in the area exposed to effluent, and reproduction and body condition indicators were more often smaller in the exposure area.

In the case of fish habitat, the most prevalent effect was a change in the benthic invertebrate community structure (measured using a similarity index), followed by a decrease in the number of species present (taxon richness). Changes in the total number of individuals (increases and decreases in density) and changes in the number of individuals of each species (measured with an evenness index) were less prevalent. The number of mines with an increased density in the area exposed to effluent was higher than the number of mines with decreased density in the exposure area. Effects observed on the number of individuals of each species were equally increases or decreases in the area exposed to effluent.

Monitoring studies conducted to assess the impact of metal mining effluents on mercury concentrations in fish tissue (use of fisheries resources) did not indicate that metal mining effluents were linked to high levels of mercury in fish tissue.

Results from EEM studies indicate that the overall sublethal toxicity (SLT) of mine effluent remained stable during the first 10 years of MMER implementation. In SLT tests, metal mining effluent had the greatest effect on invertebrate reproduction and aquatic plant growth and the least effect on fish larval growth. Mining effluent stimulated growth in plants and algae in some SLT tests.

When the presence of effects was confirmed, mines were required to conduct sampling in additional locations within the exposure area to assess the magnitude and geographic extent (M&E) of the confirmed effects. Most mines (25/29 or 86%)

[1] Effects that may be indicative of a lower risk to the environment are those with a magnitude less than an assigned critical effect size (CES). Effects that may be indicative of a higher risk to the environment have a magnitude equal to or greater than an assigned CES. See the Introduction for an explanation of critical effect sizes.

assessing the magnitude and geographic extent (M&E) of effects confirmed in the exposure area near the point of effluent discharge (near-field area) observed one or more of the same effects in the exposure area farther from the point of effluent discharge (far-field area). Half (14/25 or 56%) of the mines assessing the M&E of multiple confirmed effects observed the same multiple effects in far-field areas. In more than 50% of cases, fish effects occurring in additional locations were smaller in magnitude than effects occurring close to the discharge point. The magnitude of fish habitat effects was mainly indicative of a higher risk to the environment in both the area near the point of discharge and in additional locations within the exposure area. The distance of the additional exposure locations from the point of discharge did not influence the occurrence or magnitude of same effects.

Once the M&E of confirmed effects have been determined, mines are required to carry out a biological monitoring study designed to determine the causes of confirmed effects. Thirty-five mines conducted investigation of cause (IOC) studies. Two general categories of effects were investigated: inhibitory effects that can be caused directly by toxicity and habitat alteration or indirectly by food limitation or toxic substances contained in prey organisms; and stimulatory effects that can be caused by eutrophication due to nutrient addition to the environment. About half of the mines carrying out IOC studies examined predominantly inhibitory effects and the remaining mines examined predominantly stimulatory effects or a mix of inhibitory and stimulatory effects. Some mines have completed their IOC studies and other mines have completed part one of a two-part IOC study.

Of the 26 mines that had completed IOC studies, 77% (20/26) identified current mine effluent as a primary or possible contributing cause of effects. Two mines identified mine-related substances as a cause, but did not indicate if current mine effluent was the source, and four mines indicated that effects were caused by non-mine related factors. Major ions and phosphorus in effluent tended to be associated with stimulatory effects, whereas metals, selenium and total suspended solids in effluent were more often associated with inhibitory effects. Nitrogen compounds in effluent were associated with both stimulatory and inhibitory effects.

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## 1.0 Introduction

The *Metal Mining Effluent Regulations* (MMER) came into force in 2002 under the *Fisheries Act*. The Regulations prescribe discharge limits for arsenic, copper, cyanide, lead, nickel, zinc, total suspended solids, radium 226 and pH, and require that the effluent not be acutely lethal to rainbow trout. These end-of-pipe limits provide a national standard that is intended to protect fish, fish habitat and the use of fisheries resources. The metal mining sector is achieving over 95% compliance with the prescribed discharge limits and meeting the requirement that effluent not be acutely lethal to rainbow trout (Environment Canada 2015).

In addition to complying with end-of-pipe limits, Canadian metal mines subject to the MMER (Appendix A, Figure A1) are required, as a condition governing their authority to discharge effluent, to conduct environmental effects monitoring (EEM) studies of the potential effects of metal mine effluents on fish, fish habitat and the use of fisheries resources. Information obtained through EEM supports the evaluation of the effectiveness of the Regulations in protecting the aquatic environment and of current and future pollution prevention and control technologies, practices and programs within the mining sector. The purpose of this report is to present the major findings of the EEM studies conducted by metal mines across Canada.

In the MMER, an “effect” is defined as a statistical difference between specific data collected from an exposure area and a reference area. An exposure area means all fish habitat and waters frequented by fish that are exposed to mine effluent and a reference area means water frequented by fish that is not exposed to mine effluent and that has fish habitat that, as far as practicable, is most similar to that of the exposure area. The presence or absence of an effect is considered confirmed when a similar type of effect or an absence of an effect has been observed in two consecutive studies.

Environmental effects monitoring studies required by the MMER consist of biological, effluent and water quality monitoring studies. Biological monitoring studies to assess potential effects of mine effluent are undertaken on the following components of the aquatic receiving environment:

- fish population to assess effects on fish health;
- benthic invertebrate community to assess effects on fish habitat; and
- fish tissue to assess effects on the usability of fisheries resources when conditions specified in the MMER are met.

Biological monitoring studies to investigate observed effects are conducted in order to:

- assess the magnitude and geographic extent of effects; and
- determine the causes of effects.

EEM biological monitoring studies under the MMER constitute an iterative system of monitoring and interpretation steps which are conducted every three to six years according to conditions specified in the Regulations. The type and frequency of studies is determined by the results of previous studies. Initial biological monitoring studies are undertaken to assess and confirm the presence or absence of effects. When effects are confirmed, mines are required to determine the magnitude and geographic extent of those effects, and then to investigate their causes. If the absence of effects on the benthic invertebrate community, fish population and fish tissue (if required) is confirmed, biological monitoring frequency can be reduced. To assist mines in fulfilling the regulatory requirements for EEM, Environment and Climate Change Canada (ECCC) has developed technical guidance on all aspects of EEM studies, including study design, data analysis and interpretation (Environment Canada 2012a).

Specific indicators are measured to assess the presence or absence of effects on the fish population (Appendix B, Table B1) and the benthic invertebrate community (Appendix B, Table B2). The results of these assessments determine future monitoring study requirements and contribute to an understanding of the impact that metal mining effluent may have on aquatic receiving environments. The size of observed effects is used as a non-regulatory management tool to focus the effort of investigative studies towards the greatest risk to the environment. A critical effect size (CES) is a threshold above which an effect may be indicative of a higher risk to the environment. Critical effect sizes for the fish population and benthic invertebrate community indicators were initially developed for the pulp and paper sector after EEM studies showed that most mills observed an effect on at least one of the indicators. Once validated (Munkittrick et al. 2009), these CESs (Appendix B, Table B3) were adopted for use in the metal mining sector as well.

Effluent and water quality monitoring studies, consisting of the chemical characterization and sublethal toxicity testing (SLT) of final effluent and water quality monitoring in the environment, contribute to the assessment of effluent quality and aquatic environment conditions at individual mine sites.

## 2.0 Methods

### 2.1 Studies Summarized in the Third National Assessment Report

This report focuses on the biological components of EEM studies in order to provide a national assessment of the effects of metal mining effluents on fish populations, fish habitat and the use of fisheries resources. The results of all completed biological monitoring studies undertaken to assess the presence or absence of effects that were submitted to ECCC before October 1, 2013 are summarized. In addition, biological monitoring studies submitted before June 2014 that investigated the magnitude, geographic extent and cause of observed effects are summarized. SLT and effluent characterization study results from 2003 to 2012 are also summarized in order to provide supporting information.

Before October 1, 2013, 121 metal mines in Canada had conducted biological monitoring studies, with the number of studies dependent on when the mine became subject to the MMER. Among the 121 mines that carried out studies,

- 36 mines conducted one study;
- 25 mines conducted two studies;
- 43 mines conducted three studies;
- 17 mines conducted four studies.

Mines that are now recognized closed mines are included among the 121 mines that conducted studies. Six of the 121 mines were not able to obtain the necessary data to assess effects on either the fish population or fish habitat components and some of the remaining 115 mines were not able to obtain the necessary data to assess effects on both components. Insufficient number of fish captured was the most common reason for unsuccessful fish population studies, while differences in habitat between reference and exposure areas was the most common reason for unsuccessful fish habitat studies. Table B4 (Appendix B) provides an overview of the number and type of biological studies conducted by metal mines since the coming into force of the Regulations. Studies attempted but not successfully completed are included in Table B4 but are not included in the results section of this report.

For two mines that had changed the location of the final discharge point after completing one or two EEM studies, the results of the EEM studies conducted prior to this change in location were not included in this report. Similarly, for one mine that had made an important change in the water treatment system, the results from the EEM study conducted prior to this change were not included.

### 2.2 General Methods Used to Compile Fish and Fish Habitat Study Results

The EEM biological monitoring study reports submitted by mines to ECCC were reviewed by department experts to ensure that all regulatory requirements had been fulfilled and that the studies had been conducted according to generally accepted standards of good scientific practice. The study reports presented the raw data, the analysis and interpretation of these data and the conclusions. A portion of the raw data was also submitted to ECCC in electronic format. To provide additional verification of results, ECCC experts analyzed the raw data relating to fish and benthic indicators using a statistical assessment tool (SAT)[2] developed by ECCC (Booty et al. 2009). The SAT was used to calculate the magnitude and statistical significance of differences between exposure and reference data for the five fish and four benthic invertebrate community effect indicators in cases where the biological monitoring study used the control/impact design[3] and the fish survey used lethal methods to collect the data. To take into account site-specific factors not discernible from the raw data, results from the SAT analysis were compared to results in the mine's study report. When discrepancies occurred that could not be explained by calculation error, the results from the mine's study report were used in the compilation process. Between 50 and 70% of studies were conducted using lethal methods with a control/impact sampling design and were therefore analyzed using the SAT. For studies using other types of sampling designs,[4] results from the mine's study report were used in the compilation process.

Observed effects (or absence of effects) were categorized on the basis of occurrence, magnitude and type. The effect categories, from highest potential risk to the environment to lowest potential risk, are:

- effect or confirmed[5] effect equal to or greater than the CES
- effect or confirmed[6] effect less than the CES
- unconfirmed[7] effect
- absence or confirmed[8] absence of effects

The effect category for an entire component (fish or fish habitat) was determined by the effect with the highest potential risk for that component. The overall effect category for each mine was determined by the component with the highest potential risk. Results are provided on a mine-by-mine basis in Table C1 of Appendix C.

## 2.3 Comparative Analysis of Bray-Curtis Index Significance Testing Methodologies

The mines used the Bray-Curtis Index (BCI) to assess the similarity of the structure of benthic invertebrate communities. A review carried out by Borcard and Legendre in 2013 for ECCC determined that the methodology described in the EEM technical

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[2] Details on the statistical procedures for SAT can be found in Environment Canada 2012b.
[3] The control/impact design is when sampling occurs in distinct exposure and reference areas as opposed to a gradient design where sampling occurs along a gradient of decreasing effluent concentration.
[4] For example, gradient, nonlethal, caged bivalves or mesocosm designs.
[5] Two consecutive studies observing a similar effect with a magnitude equal to or greater than the CES in at least one study.
[6] Two consecutive studies observing a similar effect with a magnitude less than the CES or an unknown magnitude relative to the CES.
[7] Two consecutive studies, one study observing effects and one study observing an absence of effects, or two consecutive studies observing a similar effect but in different directions. The direction of an effect is determined by exposurevalues being higher or lower than reference values.
[8] Two consecutive studies observing an absence of effects.

guidance document (Environment Canada 2012a) for calculating the statistical significance of differences observed in BCI data between exposure and reference areas has a higher-than-recommended probability of returning a false positive result (i.e., identifying an effect when no effect is present). Borcard and Legendre suggested a revised methodology for testing the significance of differences in BCI data. ECCC will recommend the use of this revised methodology in EEM technical guidance going forward.

The information relating to the presence or absence of effects on benthic invertebrate community structure (Bray-Curtis Index) in this third assessment report was obtained using the existing methodology. To quantify the occurrence of false positives, ECCC conducted a comparative analysis of the results obtained with the two methodologies for the same data. Mines with a confirmed effect on the BCI and for which a false positive would affect decision making regarding the type of biological monitoring study required in the future were chosen for the comparative study. Two groups of mines were selected. The first group included seven mines that had confirmed an effect on the BCI and had not confirmed effects on any other fish habitat or fish indicators. The second group included 12 mines that had confirmed an effect on the BCI and had not confirmed effects on any other fish habitat indicators, but had confirmed effects on at least one fish indicator.

Data from 38 studies were used to compare results for these 19 mines. For each of the 38 studies, the significance of the difference between exposure and reference BCI data was re-calculated using the revised methodology. In all 38 studies, the revised methodology indicated that there was still a statistically significant difference (an effect) between exposure and reference BCI data. The agreement in results between the existing and the revised methodologies is consistent with the prediction made by Borcard and Legendre (2013) that there would be only a few differences in findings for the two methodologies. For the mines used in the comparative analysis, this means there were no observations of false positive BCI effects resulting from the use of the existing methodology. The BCI results from the 38 studies could therefore be used with confidence in the overall compilation of observed effects. Comparative analyses of other BCI results were not conducted since, for all other studies, effects were observed on other fish habitat indicators in addition to the BCI. The elimination of a false BCI effect in these studies would not have impacted decisions made regarding the type of biological monitoring studies required in the future.

## 3.0 Presence or Absence of Effects

### 3.1 Overall Effects

Of the 82 mines that had completed two or more biological monitoring studies to assess effects on fish and/or fish habitat, 76% (62/82) confirmed the presence of at least one effect (Figure 1) and approximately half (32/62 or 52%) of these mines confirmed effects on both fish and fish habitat indicators. Ninety-two percent (57/62) of mines with confirmed effects observed at least one effect equal to or greater than the CES. This included 45 mines where the effect was equal to or greater than the CES in both consecutive studies used to confirm effects and 12 mines where the effect was equal to or greater than the CES in one study and less than the CES in the other study used to confirm effects. Variable results between consecutive studies were observed by 23% (19/82) of mines, resulting in unconfirmed effects. One mine confirmed the absence of effects on fish, fish habitat and the use of fisheries resources.

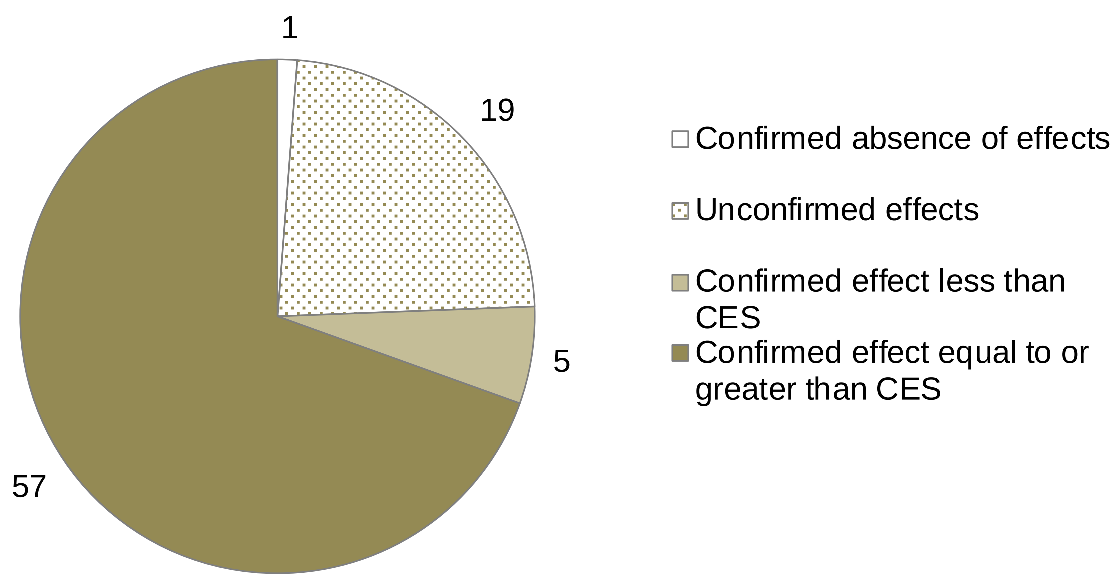


**Figure 1.** Effect categories for mines completing two or more studies to assess effects on fish and/or fish habitat

Of the 33 mines with a single completed biological monitoring study for both the fish and fish habitat components, 31 mines observed effects and 25 observed at least one effect equal to or greater than the CES. Two mines observed an absence of effects on all fish and fish habitat (benthic invertebrate community) indicators that were successfully assessed (Figure 2).

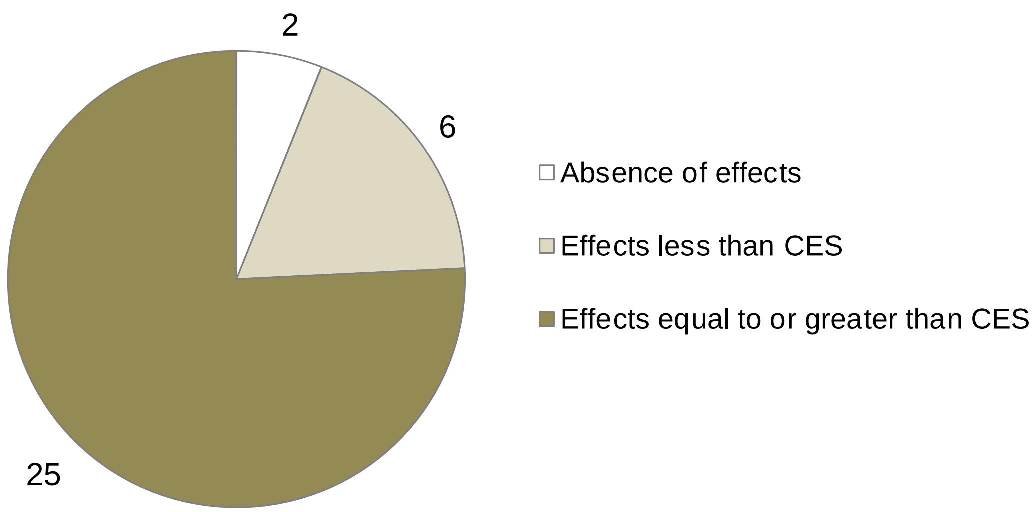


**Figure 2.** Effect categories for mines completing a single study to assess effects on fish and fish habitat

3.2 Effects on Fish

The indicators used to assess effects on fish include growth, reproduction, body and liver condition, and survival. Sixty-six mines completed at least two studies to assess effects on the fish population and 66% (44/66) of these mines confirmed an effect on at least one fish effect indicator (Figure 3). Sixty-four percent (28/44) of mines confirming effects observed at least one effect equal to or greater than the CES. This included 19 mines with effects equal to or greater than the CES in both studies and 9 mines with effects equal to or greater than the CES in one study and less than the CES in the other study used to confirm effects. Unconfirmed effects were observed by 29% (19/66) of mines and 3 (5%) mines confirmed an absence of effects on all fish indicators.

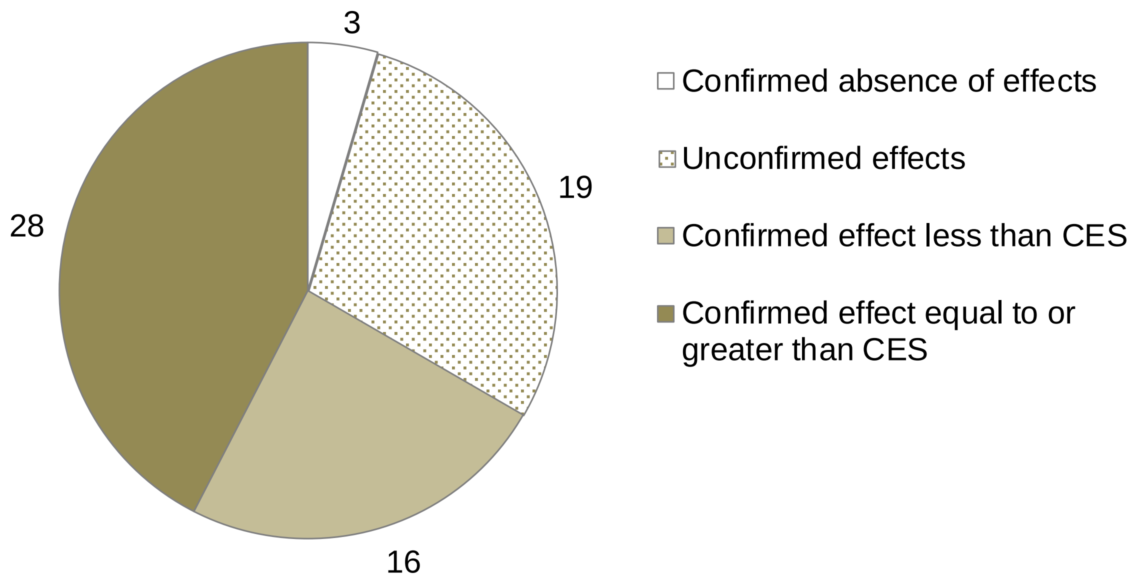


**Figure 3.** Fish effect categories for mines completing two or more studies

The effect categories for each fish population indicator for the 66 mines having completed at least two fish population studies are shown in Figure 4. The lowest number of mines is found in the confirmed absence of effect category, followed by the confirmed effects and unconfirmed effects categories. The proportion of mines observing unconfirmed effects on a specific indicator ranged from 47 to 57%. Of the 44 mines observing confirmed effects, 36% confirmed effects on one indicator, 30% on two indicators, 13.5% on 3 indicators, 16% on four indicators and 4.5% on all indicators. It should be noted however, that some studies did not obtain sufficient data to assess all indicators.

For the indicators of survival, growth and body condition, the number of mines with confirmed effects less than the CES was similar to the number of mines with confirmed effects equal to or greater than the CES. Confirmed effects on reproduction and liver condition were more often equal to or greater than the CES. Depending on the indicator, for 55 to 60% of the mines that observed confirmed effects, survival, growth and liver condition were larger and reproduction and body condition were smaller in the area exposed to effluent compared to unexposed areas.

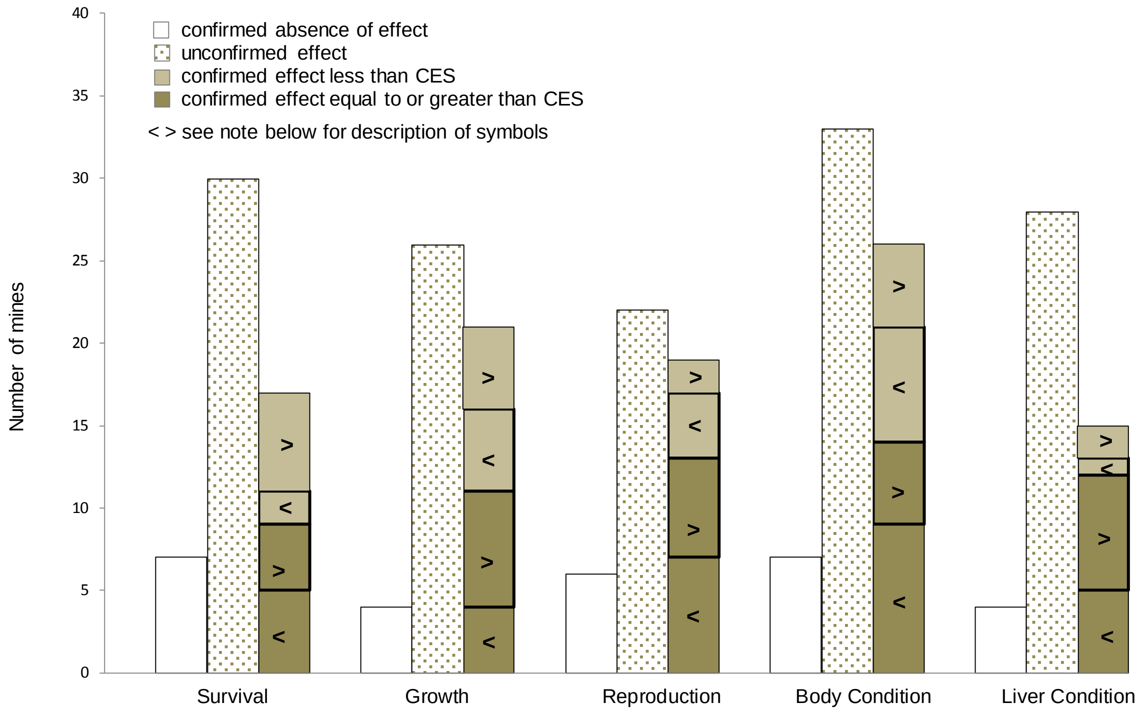


**Figure 4.** Effect categories for each fish population indicator for 66 mines completing two or more fish population studies

Note: Some studies did not obtain sufficient data to assess all indicators. Effects are denoted as > when the indicator was larger in the exposure area relative to the reference area and denoted as < when the indicator was smaller in the exposure area relative to the reference area. The "confirmed effect less than CES" category includes mines with confirmed effects of unknown magnitude relative to the CES (5 for survival, 7 for growth and 3 for body condition). The "confirmed effect equal to or greater than CES" category includes mines with confirmed effects of variable magnitude between studies (5 for survival, 2 for growth, 9 for reproduction, 6 for body condition and 4 for liver condition).

A total of 39 mines completed a single study assessing effects on the fish population. Of these 39 mines, 95% observed effects and half of these mines observed at least one effect equal to or greater than the CES (Figure 5). One mine observed no statistically significant differences between their exposure and reference sites (referred to as an absence of effects) on all fish population indicators. Another mine observed an absence of effect on survival and body condition, but growth, reproduction and liver condition could not be assessed with the information obtained by the study.

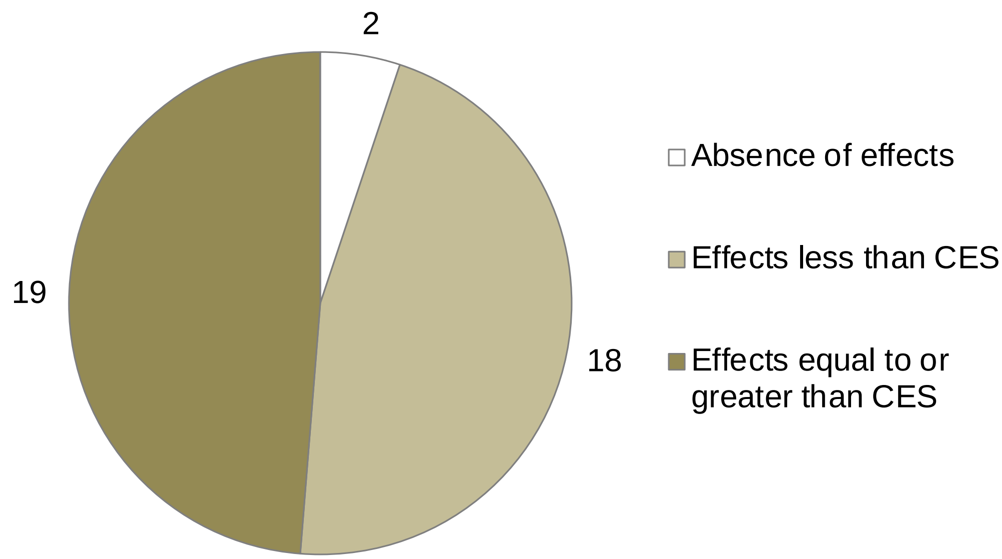


**Figure 5.** Fish effect categories for mines completing a single study

Effect categories for each of the fish population indicators for the 39 mines having completed a single fish population study are shown in Figure 6. The proportion of mines that observed effects on survival or reproduction was 54 and 48%, respectively. For growth, liver condition and body condition, the proportion varied between 70 and 75%. For all indicators, the mines more often observed effects less than the CES than effects equal to or greater than the CES.

In the case of the mines that observed effects, four of the five fish population indicators were more often larger in the area exposed to effluent than in the reference area. The percentage of mines that observed effects for which the indicators were larger in the exposure area was as follows: 58% for survival, 56% for growth, 61% for body condition and 53% for liver condition. The percentage of mines that observed effects for which the indicators were smaller in the exposure area was 57% for reproduction.

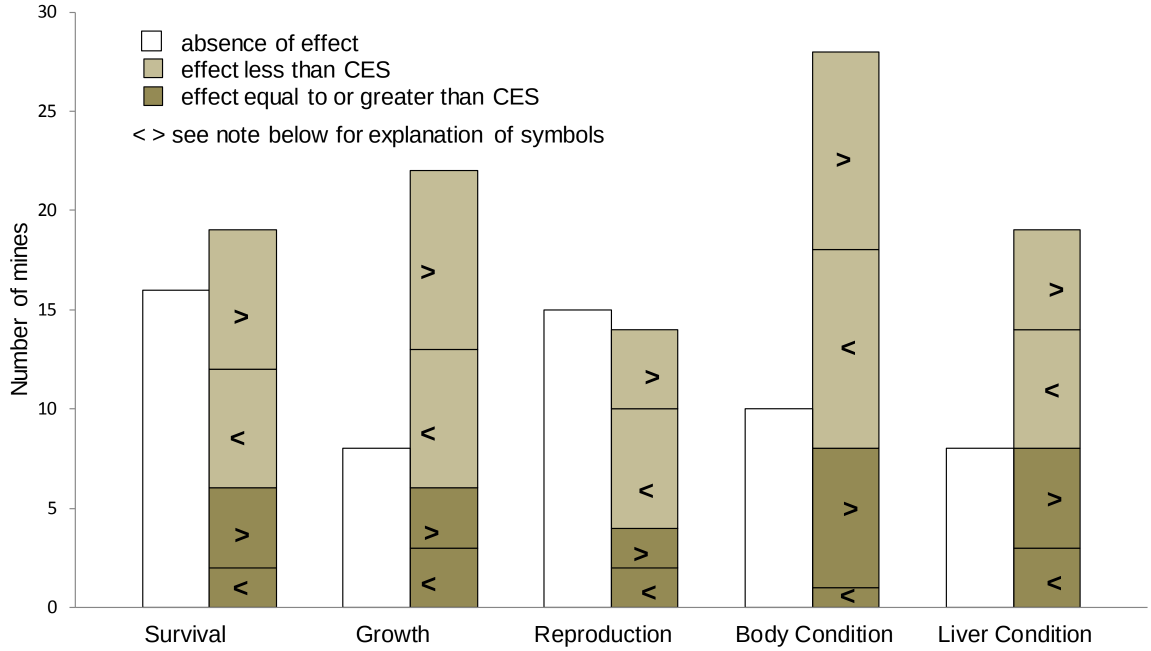


**Figure 6.** Effect categories for each fish population indicator for 39 mines with a single completed fish population study

Note: Some studies did not obtain sufficient data to assess all indicators. Effects are denoted as > when the indicator was larger in the exposure area relative to the reference area and denoted as < when the indicator was smaller in the exposure area relative to the reference area. The "effect less than CES" category includes effects of unknown magnitude relative to the CES (8 for survival, 11 for growth, 6 for reproduction, 11 for body condition and 4 for liver condition).

## 3.3 Effects on Fish Habitat

The indicators used to assess effects on fish habitat are total benthic invertebrate density, the evenness index, taxon richness and the similarity index (Bray-Curtis Index). Eighty-one mines completed two or more studies to assess effects on fish habitat, and 64% (52/81) of these mines confirmed an effect on at least one fish habitat indicator. One mine reported that all confirmed effects were less than the CES. Fifty-one mines reported that at least one effect was equal to or greater than the CES. This included 38 mines with effects equal to or greater than the CES in both studies used to confirm effects and 13 mines with effects equal to or greater than the CES in one study and less than the CES in the other study used to confirm effects. Unconfirmed effects were observed by 32% (26/81) of these mines and four percent (3/81) of mines confirmed an absence of effect on all four fish habitat indicators (Figure 7).

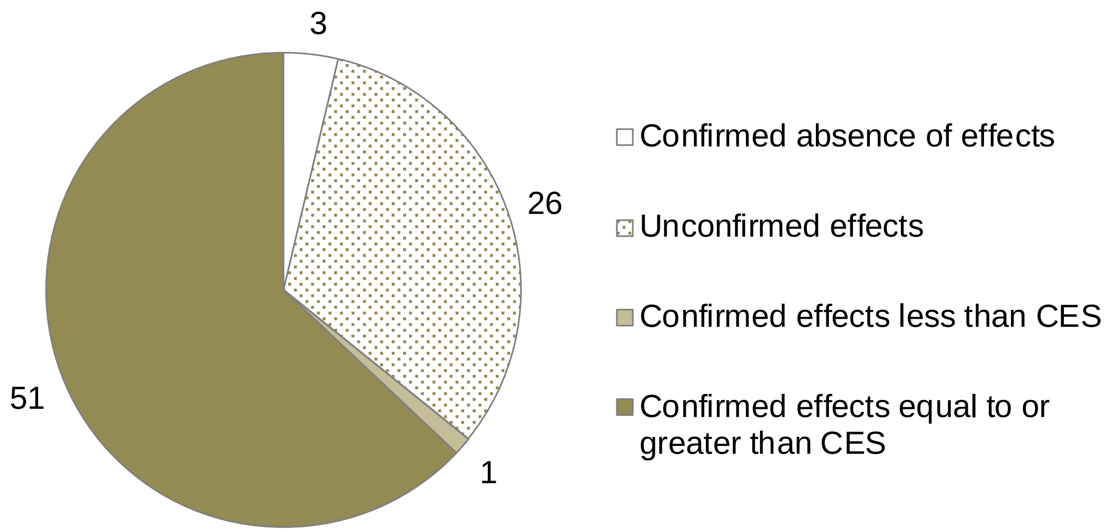


**Figure 7.** Fish habitat effect categories for mines completing two or more studies

The effect categories for each fish habitat indicator for the 81 mines having completed at least two fish habitat studies are shown in Figure 8. For density, taxon richness and evenness, the highest number of mines is found in the confirmed absence of effect category, followed by unconfirmed effects and confirmed effects. With regard to the similarity index, more mines observed confirmed effects than a confirmed absence of effects, and the proportion of mines observing unconfirmed effects was similar to the other three indicators. Confirmed effects on fish habitat were almost always equal to or greater than the CES.

Approximately half (27/52) of the mines with confirmed effects on fish habitat observed confirmed effects on two or more fish habitat indicators, and the other 25 mines observed a single confirmed effect on fish habitat. The similarity index (Bray-Curtis Index) was the single confirmed effect on fish habitat for 19 of these mines, 12 of which also observed confirmed effects on fish population indicators. The comparative analysis, described in section 2.3, confirmed that there were no observations of false positive effects resulting from the use of the methodology used in the EEM technical guidance document (Environment Canada 2012a) to calculate the statistical significance of differences observed in the Bray-Curtis Index.

Most of the confirmed effects on taxon richness consisted of decreases observed in the area exposed to effluent, whereas the confirmed effects on evenness consisted of an equal number of indicator increases or decreases observed in the exposure area. The number of mines with confirmed increases in density in the area exposed to effluent was higher than the number of mines with confirmed decreases in density.

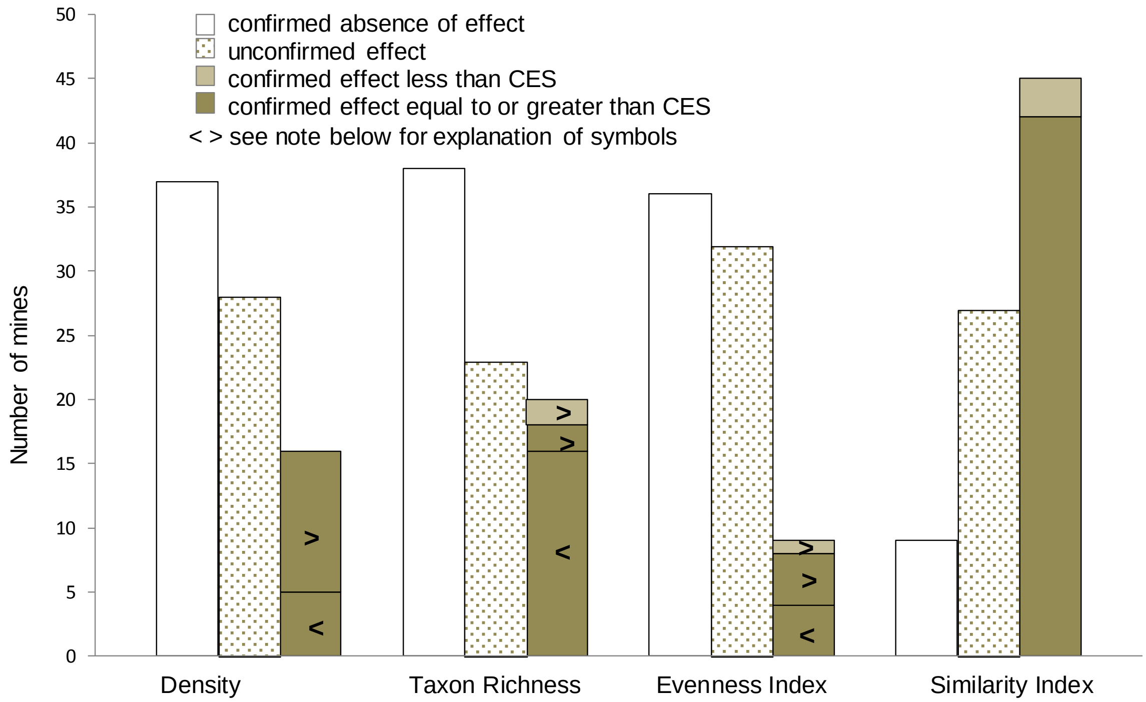


**Figure 8.** Effect categories for each fish habitat indicator for 81 mines completing two or more fish habitat studies

Note: Effects are denoted as > when the indicator was larger in the exposure area relative to the reference area and denoted as < when the indicator was smaller in the exposure area relative to the reference area, Similarity Index is neither smaller or larger, but denotes a non-directional degree of difference. The “confirmed effect equal to or greater than CES” category includes some mines with confirmed effects of variable magnitude between studies (4 for density, 6 for taxon richness, 1 for evenness and 14 for similarity). Four mines could not assess evenness.

Thirty-four mines completed a single study to assess effects on fish habitat and 82% (28/34) of these mines observed effects. Three quarters (21/28) of the mines with effects observed at least one effect equal to or greater than the CES. Six of the 34 mines (18%) observed an absence of effect on all fish habitat indicators (Figure 9).

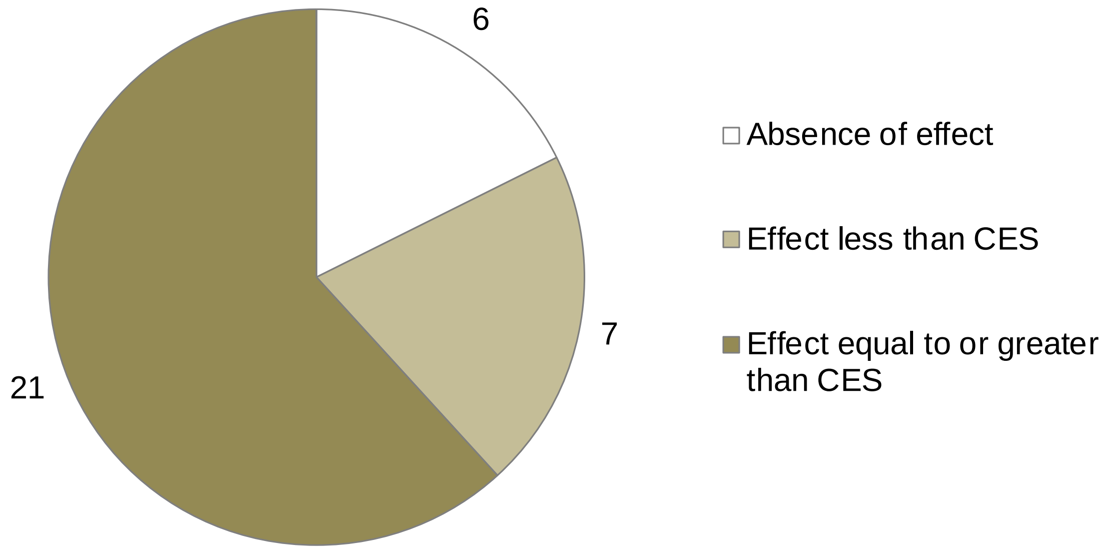


**Figure 9.** Fish habitat effect categories for mines completing a single study

Effect categories for each of the fish habitat indicators for the 34 mines having completed a single fish habitat study are shown in Figure 10. Half of the mines observed an effect on density and 70% observed an effect on the similarity index. Effects on taxon richness and evenness were observed at just over a quarter of the mines.

The effects on density and taxon richness were most often found to be a reduction in the indicator in the exposure area compared to the reference area. For the evenness index, the number of mines with observed effects that showed lower values in the exposure area relative to the reference area was similar to the number of mines with observed effects that showed higher values in the exposure area relative to the reference area. Similarity index calculations produce a unidirectional measure of change in benthic invertebrate community structure.

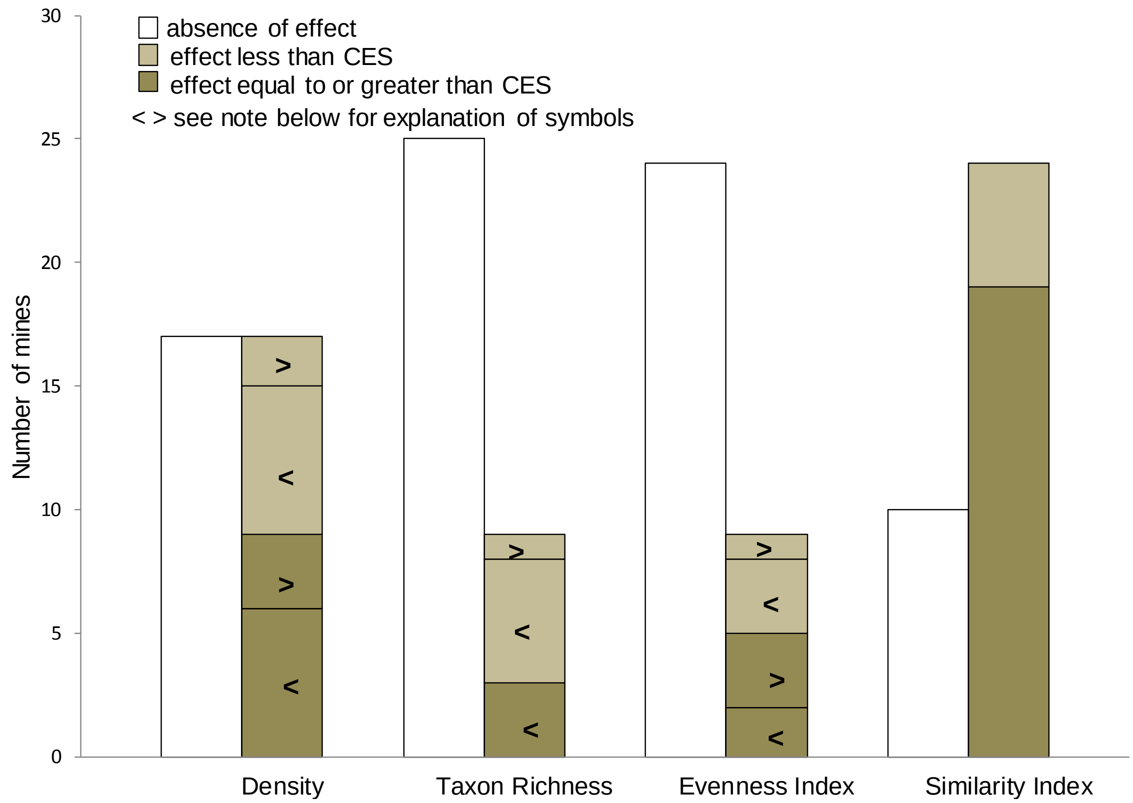


**Figure 10.** Effect category for each fish habitat indicator for 34 mines with a single completed fish habitat study

Note: Effects are denoted as > when the indicator was larger in the exposure area relative to the reference area and denoted as < when the indicator was smaller in the exposure area relative to the reference area, Similarity Index is neither smaller or larger, but denotes a non-directional degree of difference. Five mines conducted more than one benthic study but the results from only one study were usable. For one mine, the "effect less than CES" category for density, taxon richness and similarity includes effects of unknown magnitude relative to the CES. Evenness could not be assessed for one mine.

### 3.4 Effects on the Usability of Fisheries Resources

The potential effect of metal mining effluent on the usability of fisheries resources is assessed through a study measuring the concentration of mercury in fish tissue. A study is required when the concentration of mercury in final effluent is equal to or greater than 0.10 µg/L (MMER, Schedule 5, section 9).

Since 2002, 56 mines have conducted 67 studies of mercury concentrations in fish tissue. Two studies were not successful: one because the species tested in the exposure area was different than the species tested in the reference area, and another study, using caged bivalves, because the cages at the exposure site could not be relocated for recovery. Sixteen studies were conducted on a voluntary basis, given that the total mercury concentration in the effluent was less than 0.10 µg/L. The reasons for conducting a fish tissue study on a voluntary basis included: 1) exploring the historical mine-related influences on fish tissue mercury levels, 2) satisfying provincial requirements, 3) participating in joint studies organized by the Quebec Mining Association, and 4) proactively assessing potential current mine-related effects.

An “effect on fish tissue” is defined in the MMER as measurements of concentrations of total mercury that exceed 0.5 µg/g wet weight in fish tissue taken in an exposure area and that are statistically higher than the concentrations of total mercury in fish tissue taken in a reference area.

The mean total mercury concentration in fish was calculated using raw data on mercury concentrations in fish tissue that were submitted by mines electronically. These means were compared with the results reported in the study. If raw electronic data were not available, the means presented in the study reports were used. The statistical difference between the mean total mercury concentrations in fish tissue from the exposure area and reference area was determined by the mines and presented in the study reports. Mean total mercury concentrations in fish tissue obtained for the exposure and reference areas by each mine and the fish species tested are shown in Appendix D, Figures D1 to D3.

An effect on fish tissue, as defined in the MMER, was observed in one study (Figure 11). The mine in question reported that the fish tissue effect was caused by historical contamination present in the exposure area and was not due to current mine effluent.

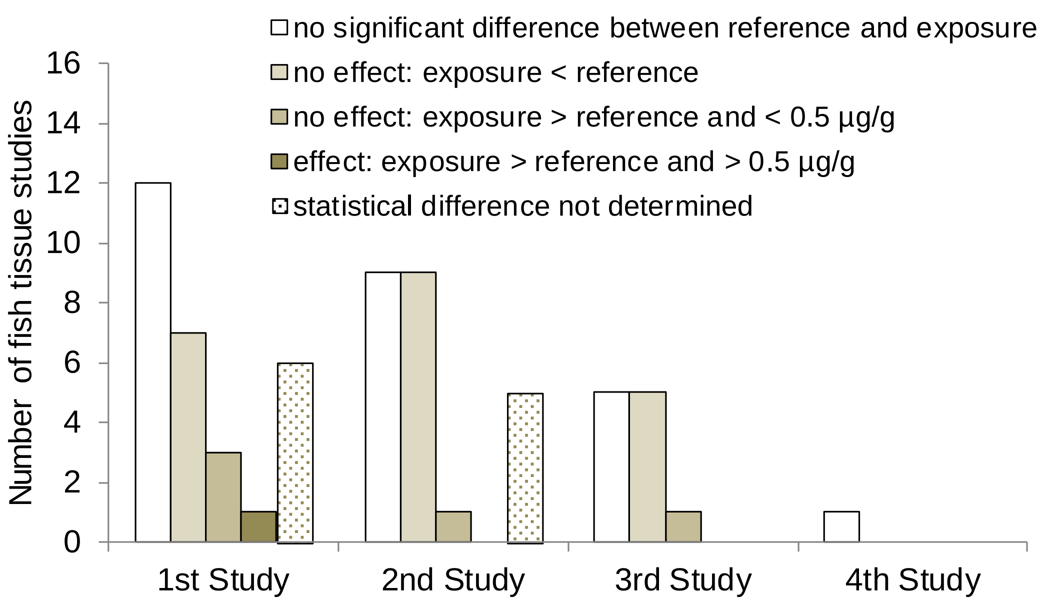


**Figure 11.** Effect categories for 65 fish tissue studies conducted in each biological monitoring study period

Note: Eleven studies did not determine the statistical difference between the two sampling areas because either the total mercury concentrations in fish tissue taken in the exposure area were lower than the concentrations in the reference area or the total mercury concentrations in effluent-exposed fish were lower than the MMER defined effect level.

## 4.0 Effluent Quality

### 4.1 Sublethal Toxicity Testing

Sublethal toxicity (SLT) testing is conducted on metal mining effluent from the final discharge point with potentially the most adverse environmental impact as per the MMER (Schedule 5, subsection 5(2)). Like effluent characterization and water quality monitoring,[9] SLT testing provides supplementary information for the biological monitoring studies, including measures of year-to-year changes in effluent quality and site-specific estimates of the potential effects of effluent on biological components in the receiving environment.

Sublethal toxicity testing involves exposing test organisms to a range of effluent concentrations under laboratory conditions. The effluent concentration that causes 25% inhibition ($IC_{25}$) in a test organism is determined. The test method that is used dictates the inhibition parameter, such as inhibition of growth or reproduction. A low $IC_{25}$ (e.g., 10%) indicates a higher level of sublethal toxicity, because the inhibition occurred at a low effluent concentration. A higher $IC_{25}$ indicates a lower level of sublethal toxicity. When the $IC_{25}$ is reported as ≥100%,[10] the effluent is considered to be non-toxic for the sublethal effect being considered for the organism concerned.

Mines are required to conduct SLT testing twice per calendar year for the first three years, and once per year thereafter. Tests are conducted using standardized methods referenced in the MMER (Schedule 5, section 5) and several different tests are required including a fish early-life-stage development test, an invertebrate reproduction test, and plant and algal growth inhibition tests.

SLT testing results from the first 10 years of MMER implementation were compiled to assess the trends in effluent quality presented in this report. Effluent sublethal toxicity was examined for all mines combined and for mines with different ore types: precious metals (gold, silver), base metals (e.g., copper, zinc, and nickel), uranium, iron, and other ore types (e.g., tantalum, titanium, tungsten). Trends were examined over the 10-year period from 2003 to 2012. During this period, a total of 6,761 test results were submitted by 125 mines.

Annual geometric means[11] of $IC_{25}$ values were calculated for all mines combined and for each ore type, for each year. $IC_{25}$ values from each year were sorted into three SLT categories: higher toxicity ($IC_{25} \leq 20\%$), lower toxicity ($IC_{25} > 20\%$ and <100%) and no toxicity ($IC_{25} \geq 100\%$). The geometric mean $IC_{25}$ and percent of $IC_{25}$ values in each SLT category is shown for each year for each of the five freshwater SLT tests in Appendix E.

[9] Water quality monitoring data not summarized in this report.
[10] For plant and algal growth inhibition tests, no toxicity is indicated by $IC_{25} \geq 91\%$ and $IC_{25} \geq 97\%$ because the test methods require the addition of nutrient which results in the dilution of effluent.
[11] The geometric mean is calculated as the *n*th root of the product of *n* numbers. The geometric mean, as opposed to the standard mean, is the recommended statistic for presenting SLT data because it de-emphasizes extreme values.

The annual geometric mean $IC_{25}$ for each ore type for freshwater SLT test is shown in Appendix F.

4.1.1 Sublethal Toxicity of Mine Effluent

With the exception of the algal growth inhibition test, the overall sublethal toxicity of mine effluent remained stable between 2003 and 2012 (Figure 12). Algal growth inhibition decreased from 2007 to 2011, as shown by increases in $IC_{25}$ geometric means and decreases in the proportion of "high toxicity" results ($IC_{25} \leq 20\%$) (Figure E4). Sublethal toxicity testing results for fish (*Pimephales promelas)* larval growth, invertebrate (*Ceriodaphnia dubia)* reproduction, and plant (*Lemna minor)* growth inhibition tests showed year-to-year variation, but no consistent trends over time (Figure 12).

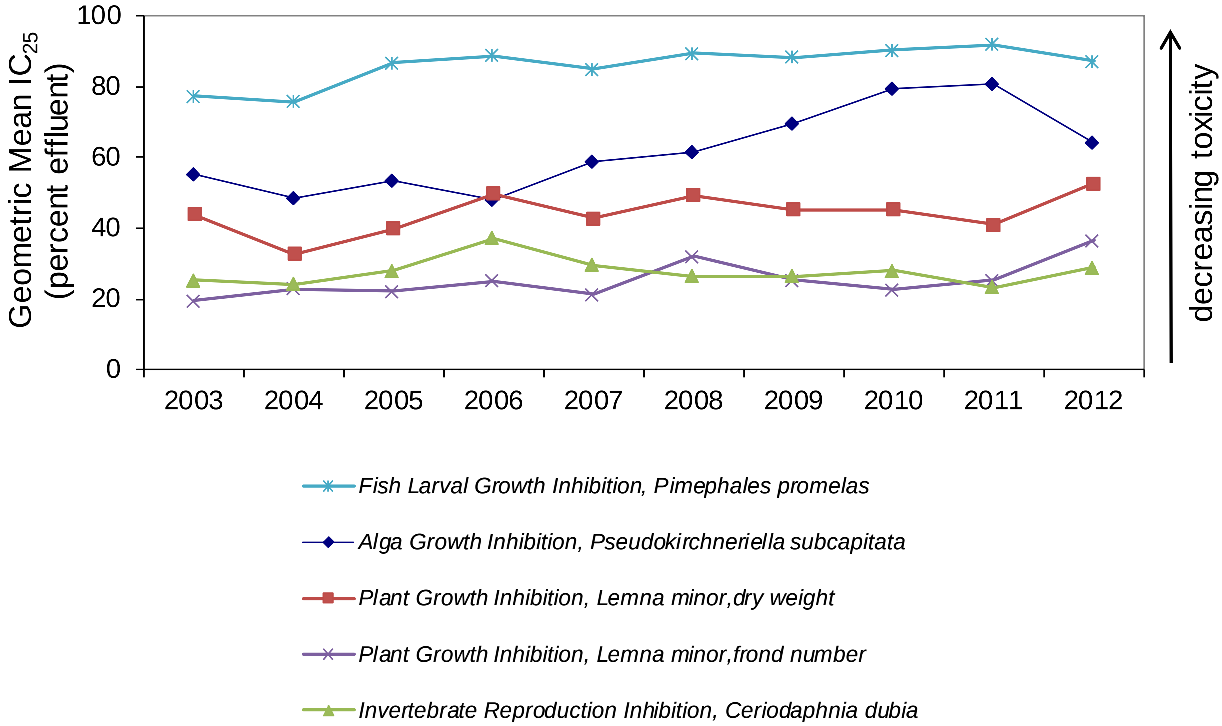


**Figure 12.** Annual geometric mean $IC_{25}$ (percent effluent on a volume basis) for all mines, for each freshwater SLT test

Note: Ranges in number of tests conducted per year were as follows: *Pimephales promelas*, n = 111–140; *Pseudokirchneriella subcapitata*, n = 119–152; *Lemna minor* dry weight, n = 117–142; *Ceriodaphnia dubia*, n = 121–155 ; *Lemna minor* frond number, n = 116–145.

Trends in effluent sublethal toxicity were more variable for different ore types, likely due to the smaller data set size for ore type analyses (Figures F1-F5). The results from base and precious metal mines on algal growth showed decreases in toxicity between 2007 and 2011 and an increase in 2012. Although some trends may be apparent for uranium, iron and "other" ore types, they should be interpreted with caution given the small sample sizes.

In locations where *Pimephales promelas* (fathead minnow) is not an indigenous species, an analogous fish test is conducted using rainbow trout (*Oncorhynchus mykiss*). Eight base and two precious metal mines submitted SLT results for tests conducted on rainbow trout between 2003 and 2012. These mines were located predominantly in western Canada. For base metal mines, rainbow trout $IC_{25}$ values ranged from 54 to 100%, and 62% of tests indicated no sublethal toxicity ($IC_{25} \geq 100\%$). For precious metal mines, in all 22 tests conducted, no sublethal toxicity ($IC_{25} \geq 100\%$) to rainbow trout was observed.

Mines that discharge to marine or estuarine environments are required to conduct SLT tests using marine organisms and different test methods than those used for freshwater tests. Two base metal mines conducted marine SLT tests. Sand dollar $IC_{25}$ values ranged from 4 to 18%, white sea urchin $IC_{25}$ values ranged from 10 to ≥100%, red macroalgae $IC_{25}$ values ranged from 4 to 56%, topsmelt $IC_{25}$ values ranged from 67 to 73% and inland silverside $IC_{25}$ values ranged from 16 to ≥100%. There were no apparent trends in effluent sublethal toxicity over time at either mine.

### 4.1.2 Responsiveness of Sublethal Toxicity Tests

The effluent concentration at which inhibition occurs is influenced by which standardized test is used. The test that shows inhibition at the lowest effluent concentration is considered the most responsive test. The sublethal toxicity result obtained with one type of test compared to the other tests for the same effluent sample can be used to assess relative responsiveness. It is important to monitor the responsiveness of SLT tests to ensure that the tests being used are still relevant for the effluent being evaluated (for example, species that are consistently non-responsive could be removed from the testing requirements in the future). Changes to effluent quality over time are better captured using responsive tests. The responsiveness of each test compared to other tests can help predict the dominant toxicant. For example, fish are known to be more responsive to ammonia (toxic to fish) than invertebrates, whereas invertebrates are often more responsive to metals than fish. The annual geometric means of $IC_{25}$ and the proportion of tests indicating no sublethal toxicity for all mines show the relative responsiveness of each test (Figures E1 to E5).

The tests that were the most responsive to effluent were the invertebrate reproduction and plant growth (frond number) inhibition tests, for which the annual geometric means of $IC_{25}$ were in the range from ~20 to 40%. The plant growth (frond dry weight) inhibition test was slightly less responsive, with $IC_{25}$ annual geometric means ranging from ~40 to 50%, followed by the algal growth inhibition test, with a wider range of annual geometric means of $IC_{25}$, specifically ~50 to 80%. The fish early-life-stage development inhibition test was the least responsive test, with $IC_{25}$ annual geometric means in the ~80 to 90% range. The relative responsiveness of these different tests was found to be the same when the proportion of tests that indicated no sublethal toxicity was compared. These results corroborate the findings of the Second National Assessment (Environment

Canada 2012b), thus indicating that the relative responsiveness of SLT tests to metal mine effluent has remained constant through the first 10 years of testing.

The most responsive SLT tests among ore types with large data sets (precious and base metals) were the invertebrate reproduction and plant growth *(*frond number) inhibition tests (Figures E1, E2). Although the data for uranium and "other" ore types are more variable, the invertebrate reproduction and plant growth *(*frond number and dry weight) inhibition tests appeared to be the most responsive tests, and the fish early-life-stage development inhibition test, the least responsive (Figures E3, E4). For iron ore mines, there were no consistent differences in test responsiveness (Figure E5).

### 4.1.3 Stimulation in Algal and Plant Growth Inhibition Tests

The algal and plant growth inhibition test methods require that the occurrence of growth stimulation be reported. Stimulation refers to an increase in growth of test organisms relative to controls after effluent exposure. If stimulation at low concentrations is followed by an inhibitory response at higher concentrations, this low-dose stimulation may be related to an organism's response to low levels of a toxic substance. This effect is referred to as hormesis. If the stimulatory effect is observed across all effluent concentrations, or increases with increasing effluent concentration, the results may be indicative of an enrichment effect related to increased nutrient availability rather than hormesis.

From 2010 to 2012, stimulation was reported in 55% of algal growth tests and 19% of plant growth inhibition tests. Stimulation appears to be more frequent for base and precious metal mines than for other ore types, particularly in the case of the plant growth inhibition test (Table 1).

**Table 1.** Occurrence of stimulation in algal and plant growth inhibition sublethal toxicity tests (2010-2012)

| Test | Ore Type | Percent of tests with stimulation | Total number of tests conducted |
|---|---|---|---|
| Plant Growth Inhibition *Lemna minor* frond number | base metal | 26 | 135 |
| | precious metal | 19 | 177 |
| | iron ore | 6 | 31 |
| | other | 5 | 19 |
| | uranium | 0 | 23 |
| | Total | 19 | 385 |
| Algal Growth Inhibition *Pseudokirchneriella subcapitata* | base metal | 67 | 144 |
| | precious metal | 53 | 180 |
| | other | 42 | 19 |
| | uranium | 42 | 26 |
| | iron ore | 29 | 34 |
| | Total | 55 | 403 |

The overall stimulation results presented here include both types of stimulation observed—hormesis or enrichment effect—and thus likely overestimate the enrichment effect. Additional test information is needed to differentiate between these types of stimulation.

## 4.2 Effluent Characterization

Effluent characterization is conducted by analyzing a sample of effluent from each final discharge point (FDP) to determine the concentrations of substances in mine effluent that are potential contaminants. The annual mean concentration of each of the nine specified substances (MMER, Schedule 5, section 4) was calculated for two different groups of FDPs. The first group contained the FDPs associated with the biological monitoring studies and the second group contained all other FDPs. These annual means are presented in Appendix G to give a general overview of effluent chemistry.

## 5.0 Biological Monitoring Studies Investigating Observed Effects

Biological monitoring studies designed to assess and confirm effects are typically conducted in the “near-field” area, i.e., an area of higher effluent concentration located close to the effluent discharge point. When effects are confirmed and results of previous monitoring studies do not indicate the magnitude and geographic extent (M&E) of confirmed effects, mines are required to conduct biological monitoring in one or more additional sampling locations within the exposure area (MMER, Schedule 5, paragraph 19(1)(*d*)). The Metal Mining Technical Guidance for EEM (Environment Canada 2012a) recommends that M&E studies be conducted in an area of low effluent concentration, near the downstream boundary of the effluent mixing zone known as the far-field.

Once the M&E of confirmed effects have been determined, mines are required to conduct an investigation of cause (IOC) study that includes field and laboratory studies designed to determine the causes of the effects. Results from completed M&E and IOC studies are summarized in the next two sections and mine-by-mine descriptions of study results are listed in Appendix H.

### 5.1 Magnitude and Geographic Extent Studies

Magnitude and geographic extent studies have been conducted by 29 mines (27 studies).[12] Thirteen mines assessed M&E during biological monitoring studies to assess effects (i.e., prior to confirmation of effects), and 15 mines conducted M&E studies after effects had been confirmed. One mine assessed the M&E of benthic and fish effects in separate phases (before and after confirmation of effects, respectively). An additional 11 mines with confirmed effects did not sample far-field areas to assess M&E due to confounding factors in the receiving environment or because M&E could be determined from existing information. Far-field areas sampled to assess the M&E of confirmed effects observed in the near-field areas were located between 0.2 and 60 kilometres downstream from mine effluent discharge points (Figure 13a&b).[13]

Of the 29 mines that sampled far-field areas to assess M&E, 86% (25/29) reported at least one effect in the far-field area that was the same as an effect confirmed in the near-field area. Twenty-five mines assessed the M&E of multiple confirmed effects, and 56% (14/25) of these mines reported multiple far-field effects that were the same as the effects confirmed in the near-field area. Far-field effects the same as those confirmed in near-field areas were observed more frequently for fish habitat than for fish. There was no relationship between occurrence of effects in the far-field area and distance from the mine effluent discharge point.

For fish populations specifically, the M&E of confirmed effects was assessed in far-field areas by 14 mines (Figure 13a). Ten of these mines (71%) observed at least one effect

[12] Refers to M&E studies in which far-field areas were sampled; 4 mines assessed M&E in 2 joint studies.
[13] Distances were approximated from study area maps. Several mines included multiple far-field areas; distance from effluent discharge point was based on the nearest far-field area, except in cases where areas further downstream were more suitable for assessing M&E.

in far-field areas that was the same as the effect confirmed in the near-field area, with three of these mines observing multiple effects that were the same as those confirmed in the near-field area. Four mines did not observe the same confirmed near-field effects in the far-field area.

For fish habitat specifically, the M&E of confirmed effects were investigated by 28 mines (Figure 13b). Twenty of these mines (71%) observed at least one fish habitat effect in the far-field area that was the same as the effect confirmed in the near-field area, with 10 of these mines observing multiple effects that were the same as those confirmed in the near-field area. Eight mines did not observe the same confirmed near-field effects in the far-field area.

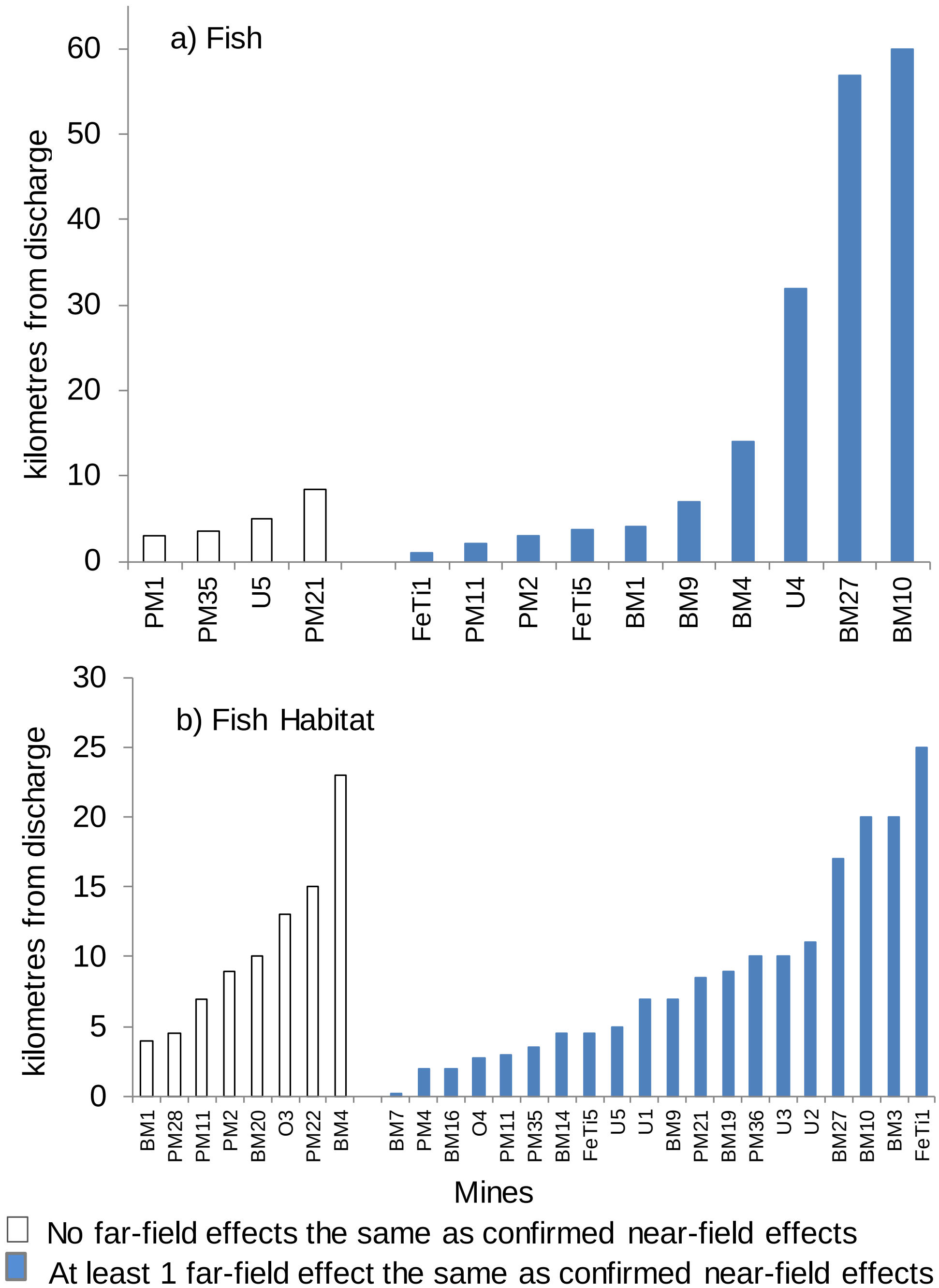


**Figure 13.** Distance from mine effluent discharge point to far-field sampling areas for mines that conducted magnitude and extent studies on a) fish and b) fish habitat effects

The number of fish effects confirmed in the near-field area that were assessed for M&E and the number of the same fish effects that were also observed in the far-field area is shown for each fish population indicator in Figure 14. Of the 51 near-field confirmed fish effects, 31% (16/51) were also observed in the far-field area. The fish effects that were observed the most in both near- and far-field areas were increased body condition, decreased growth, and decreased gonad weight (reproduction). Increased survival, decreased liver condition, and increased gonad weight (reproduction) were not observed in far-field areas. Sixty-nine percent (35/51) of the near-field confirmed fish effects were equal to or greater than the CES,[14] whereas 44% (7/16) of the far-field fish effects were equal to or greater than the CES.

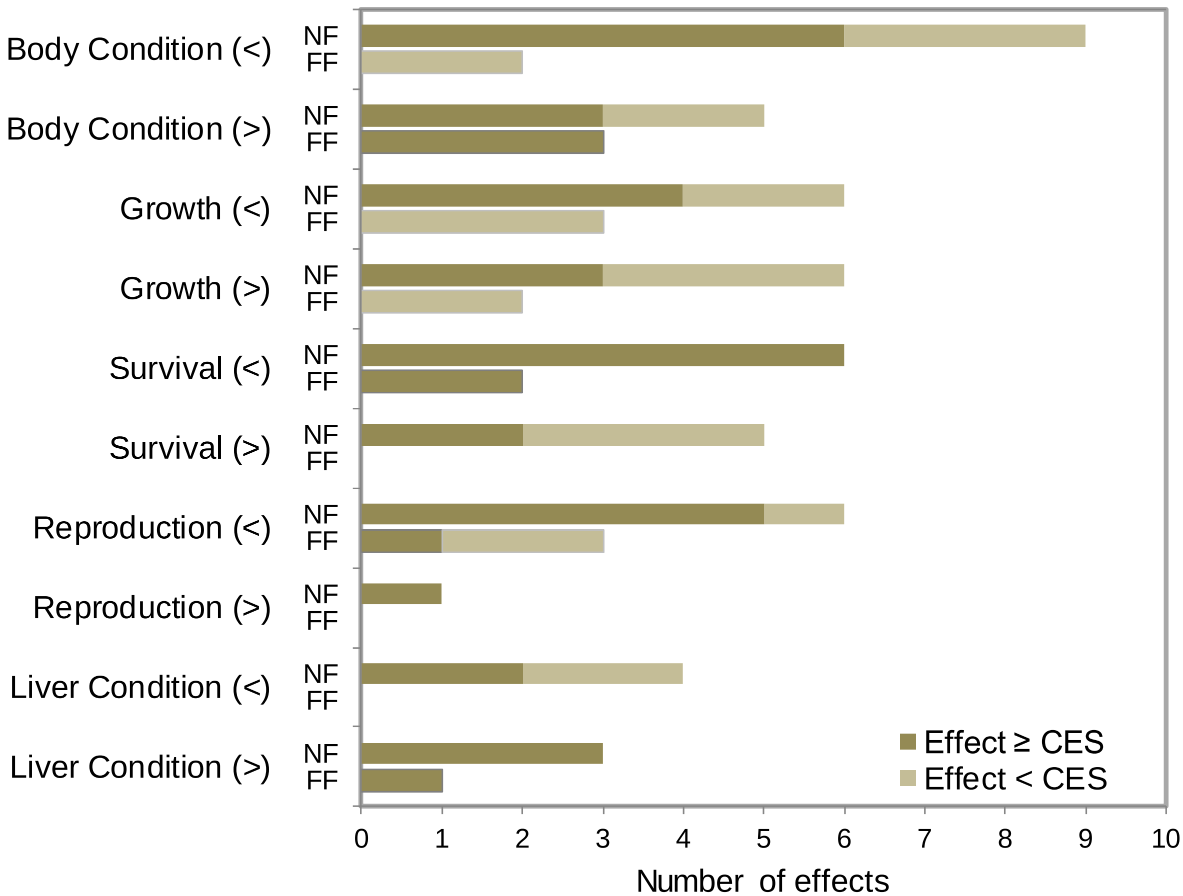


**Figure 14.** Number of confirmed near-field (NF) and same far-field (FF) effects for magnitude and geographic extent studies on fish populations
Note: Effects are denoted as > when the indicator was larger in the exposure area relative to the reference area and denoted as < when the indicator was smaller in the exposure area relative to the reference area.

The number of fish habitat effects confirmed in the near-field area that were assessed for magnitude and geographic extent, and the number of same effects that were also observed in the far-field area is shown for each fish habitat indicator in Figure 15. Of the 56 near-field confirmed fish habitat effects, 55% (31/56) were also observed in the far-field area. The fish habitat effect that was observed the most in both near- and far-field areas was an effect on the benthic invertebrate community structure (similarity index), followed by effects of increased density and decreased taxon richness. Twenty percent

[14] in at least one study

(1/5) of confirmed decreases in density were also observed in the far-field area and the single confirmed effect of increased richness was also observed in the far-field area. Effects confirmed in the near-field area on evenness were not observed in the far-field area.

Ninety-three percent (52/56) of fish habitat effects confirmed in near-field areas were equal to or greater than the CES,[15] and 87% (27/31) of far-field effects were equal to or greater than the CES. Of the four near-field confirmed effects lower than the CES, three were also observed in the far-field area, but with a magnitude equal to or greater than the CES.

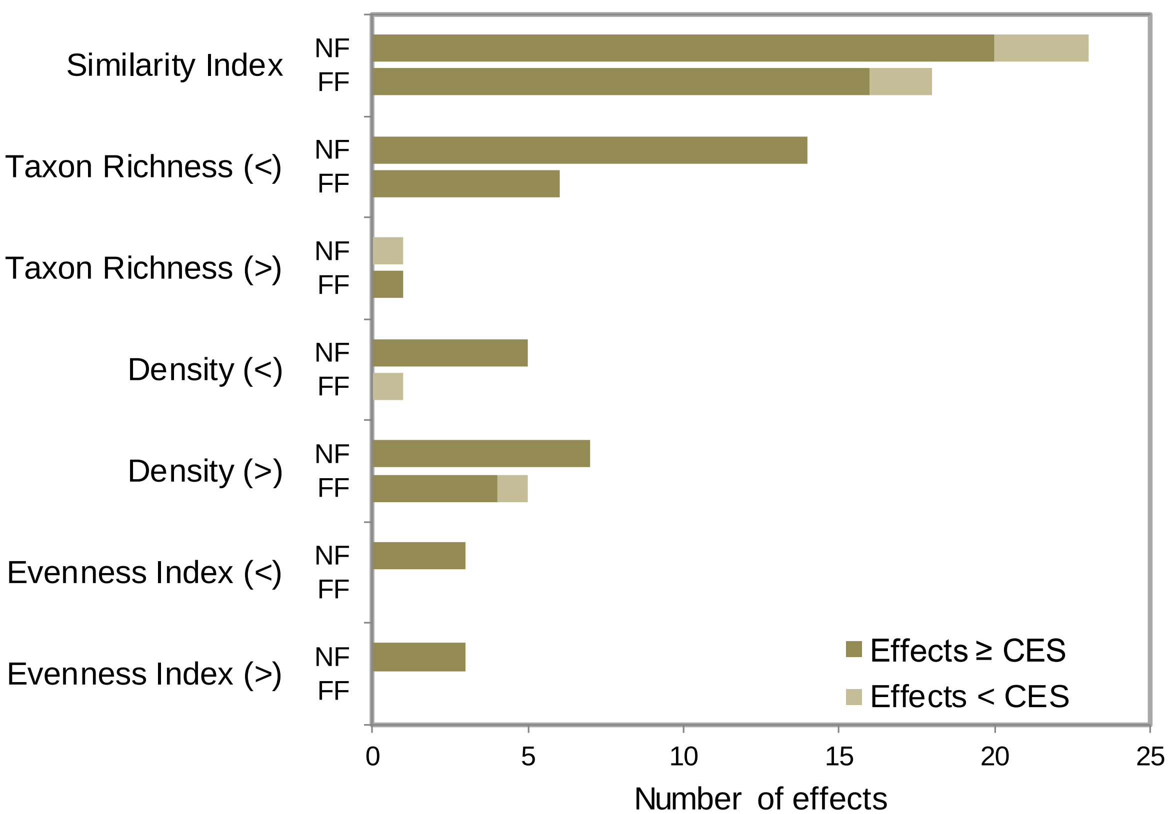


**Figure 15.** Number of confirmed near-field (NF) and same far-field (FF) effects for magnitude and geographic extent studies on fish habitat

Note: Effects are denoted as > when the indicator was larger in the exposure area relative to the reference area and denoted as < when the indicator was smaller in the exposure area relative to the reference area.

[15] in at least one study

## 5.2 Investigation of Cause Studies

Before June 2014, 35 mines had undertaken investigation of cause (IOC) studies.[16] Twenty-six of these mines have completed their IOC studies, 18 in one three-year study period[17] and eight in two consecutive three-year study periods. Nine mines are conducting ongoing IOC studies, each having completed the first of two three-year study periods.

Twenty-six mines conducted IOC studies which included new data collected through investigative field and/or laboratory studies, and nine mines conducted IOC studies based on existing information. Mines that based their IOC studies on existing information were either conducting the first of two three-year study periods (5 mines), or were investigating effects for which existing data were considered sufficient to identify cause (4 mines).

The confirmed effects under investigation included:

- effects on both fish and fish habitat (18 mines)
  - multiple fish and fish habitat effects (14 mines)
  - multiple fish effects and a single fish habitat effect (4 mines)
- effects on fish alone (5 mines)
  - multiple fish effects (2 mines)
  - a single fish effect (3 mines)
- effects on fish habitat alone (12 mines)
  - multiple fish habitat effects (6 mines)
  - a single fish habitat effect (6 mines)

Effects can be described as inhibitory or stimulatory. When the indicator measured is larger in the exposure area than the reference area, the effect is considered stimulatory. An effect is considered inhibitory when the indicator measured is smaller in the exposure area than in the reference area. Of the 35 mines conducting IOC studies, 17 investigated predominantly inhibitory effects, seven investigated predominantly stimulatory effects and 11 investigated a mix of inhibitory and stimulatory effects.

Among the 26 mines with completed IOC studies, 77% (20/26) identified at least one cause that was related to current mine effluent; 14 of these mines identified multiple potential causes including causes related to and unrelated to current mine effluent. Two mines identified effluent substances as a cause, but did not indicate if current mine effluent was the source. Four mines identified causes related to factors other than mine effluent, such as natural differences in habitat between exposure and reference areas, or sources of effluent associated with historic mining activity and urban areas.

Primary and possible contributing causes related to current mine effluent that were identified in IOC study reports include major ions, metals in mine effluent and/or

[16] Includes 7 mines that participated in 3 joint studies, for a total of 31 studies
[17] Often referred to as a phase

sediment, nitrogen compounds, sedimentation or total suspended solids (TSS), phosphorus, mine effluent in general, and selenium (Figure 16).

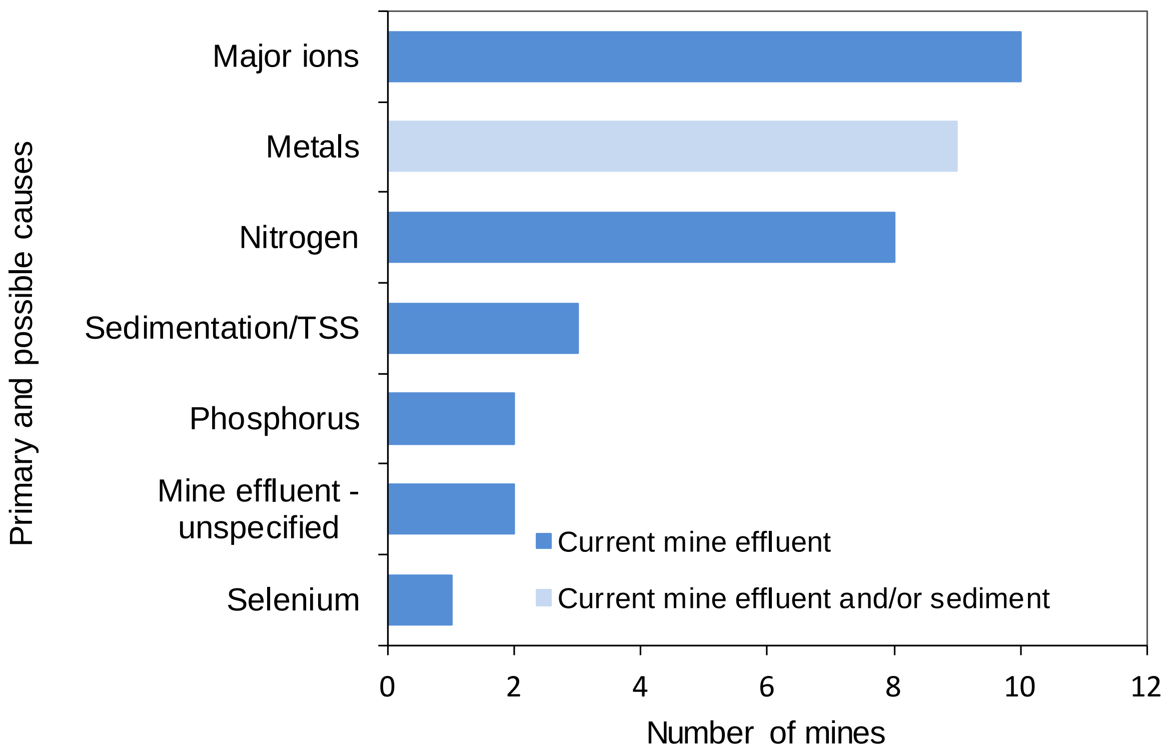


**Figure 16.** Primary and possible contributing causes related to current mine effluent identified by 20 mines that completed investigation of cause studies

Major ions in mine effluent identified by IOC studies as contributing to the cause of effects included chloride, sulphate, sodium, calcium, and potassium. Major ions were most frequently associated with stimulatory effects, with some studies suggesting they contribute to nutrient enrichment, but major ions were also reported to cause inhibitory effects. Inhibitory effects related to major ions were caused in one case by an increase in lake water total dissolved solids concentration, which reduced lake mixing and caused a depletion of dissolved oxygen at the bottom of the lake. In another case, chloride and salinity toxicity were implicated among other potential causes of inhibitory effects.

Metals identified as causes of effects included copper, nickel, cadmium, and zinc, though some studies did not identify individual metals. Selenium, a non-metal substance, was indicated as a cause along with other metals in one completed study and as a contaminant of concern in one ongoing study. Other metals and non-metal substances observed at elevated concentrations in the receiving environment[18] included

[18] Refers to elevated concentrations in water or sediment relative to surface water/sediment quality guidelines and/or reference areas

aluminum, arsenic, chromium, cobalt, iron, lead, manganese, molybdenum, nickel, strontium, and uranium.

One of the mines with completed IOC studies identified current mine effluent as the primary source of metals causing effects, and eight mines indicated that the sources of metals could include current mine effluent and/or sediment. Elevated metal concentrations in sediment could be caused by either current mine effluent discharges or historical mine activities (effluent discharges and tailings disposal occurring before MMER implementation or both). Metals were more frequently identified as the cause of inhibitory effects than stimulatory effects.

Nitrogen compounds, primarily ammonia and nitrate, were associated with both stimulatory and inhibitory effects. Several mines indicated that elevated ammonia and nitrate concentrations in mine effluent were related to the use of explosives in mining operations. Stimulatory effects were attributed mainly to nutrient enrichment, whereas some studies suggested that inhibitory effects could be related to nutrient enrichment or toxic effects of nitrogen compounds. Elevated phosphorus concentrations in mine effluent were identified as the primary cause of stimulatory effects by two mines; in both cases, the effects were attributed to nutrient enrichment.

Total suspended solids or sedimentation related to current mine effluent discharge were identified as primary or contributing causes by three mines, all of which had predominantly inhibitory effects. One of these mines indicated that benthic habitats were adversely affected by the deposition of mine-related solids, while the studies conducted by the other two mines suggested that TSS could be contributing to nutrient enrichment, despite the observation of inhibitory effects on fish habitat and fish indicators.

Potential causes identified for further investigation by the nine mines conducting ongoing IOC studies included metals in mine effluent and/or sediment (7), nitrogen compounds in mine effluent (4), non-mine-related factors (2), selenium in mine effluent (2) and major ions in mine effluent (1).[19]

[19] Includes 2 joint studies; in each study, the same confirmed effects were investigated by 2 mines

## 6.0 Key Findings

Prevalence of Effects

Most mines (62/82 or 76%) that completed studies to assess effects confirmed the presence of at least one effect, and half of the mines reporting effects (32/62 or 52%) confirmed effects on both fish and fish habitat. One mine confirmed the absence of effects on fish, fish habitat and the use of fisheries resources. Another mine observed an effect on the use of fisheries resources (mercury in fish tissue), which it attributed to historical contamination of the exposure area rather than current mine effluent.

For fish specifically, 66% (44/66) of mines that completed studies to assess effects confirmed at least one effect on fish and three mines confirmed an absence of effects on all fish indicators. Changes (increases and decreases) in the relationship between body weight and length, known as body condition, was the most prevalent fish effect observed, but changes in survival, growth, reproduction and liver condition were also observed. Survival, growth and liver condition indicators were more often larger in the area exposed to the effluent and reproduction and body condition indicators were more often smaller in the exposure area.

When considering fish habitat, 64% (52/81) of mines undertaking studies to assess effects confirmed at least one effect on fish habitat and three mines confirmed an absence of effects on all fish habitat indicators. The most prevalent confirmed fish habitat effect was a change in benthic invertebrate community structure (measured using the Bray-Curtis Index), followed by a decrease in taxon richness, changes in density (increases and decreases) and changes in the distribution of individuals among the different taxa (measured with an evenness index). The number of mines with a confirmed increase in density in the area exposed to effluent was higher than the number of mines with confirmed decreases in density in the exposure area. Confirmed effects on evenness consisted equally of increases or decreases in the area exposed to effluent. The comparative analysis, described in section 2.3, confirmed that there were no observations of false positive effects resulting from the use of the methodology specified in the EEM technical guidance document (Environment Canada 2012a) for calculating the statistical significance of differences observed in the Bray-Curtis index.

Magnitude of Effects

Almost all mines (57/62 or 92%) with confirmed effects observed at least one effect of a magnitude that may be indicative of a higher risk to the environment.[20] Sixty-four percent (28/44) of mines with confirmed fish effects and all but one of the mines with confirmed fish habitat effects, observed at least one effect of a magnitude that may be indicative of a higher risk to the environment. Confirmed effects on fish reproduction and liver condition and on all fish habitat indicators were more often of a magnitude that may be indicative of a higher risk to the environment.

[20] An effect that may be indicative of a higher risk to the environment is an effect of a magnitude that is equal to or greater than the critical effect size (CES).

Type of Effects

The types of effects identified by this third national assessment were similar to those identified by previous national assessments published by ECCC (Lowell et al. 2008, Environment Canada 2012b). Effects on growth, survival, reproduction and the condition of the body and liver were observed in fish from exposure areas. Fish habitats exposed to effluent had experienced a change in benthic invertebrate community structure and the number of individuals and species present (Table 2).

**Table 2.** Summary of confirmed effects observed on fish and fish habitat in aquatic environments receiving metal mine effluent

| **Effect Indicator** | **Compared to Reference (number of mines)** | |
|---|---|---|
| Fish | | |
| body condition | fatter fish (10) | thinner fish (16) |
| liver condition | larger livers (9) | smaller livers (6) |
| reproduction | larger gonads (8) | smaller gonads (11) |
| growth | faster growing (12) | slower growing (9) |
| survival | older fish (10) | younger fish (7) |
| Fish Habitat (benthic invertebrate community) | | |
| density | more individuals per unit area (11) | fewer individuals per unit area (5) |
| taxon richness | more species (4) | less species (16) |
| evenness index | more even distribution among taxa (4) | less even distribution among taxa (5) |
| similarity index | change in community structure (45) | |

Effluent Quality

The overall sublethal toxicity of mine effluent remained stable during the first 10 years of MMER implementation. Algal growth inhibition decreased from 2007 to 2011, suggesting a possible trend of decreasing effluent sublethal toxicity to algal growth; however, sublethal toxicity increased again in 2012. Among individual mine ore types, the same trends of decreasing algal sublethal toxicity were noted for base and precious metal mines and sublethal toxicity increased for algal growth in 2012. For uranium, iron, and “other” ore types, meaningful trends were difficult to identify because of the small number of tests conducted each year and high year-to-year variability. The most responsive tests for metal mining effluent were the invertebrate reproduction and aquatic plant growth (frond number) inhibition tests. The least responsive test was the fish larval growth inhibition test. During the time period in which incidences of stimulation (increased growth) were reported, between 2010 and 2012, stimulation was observed in 19% and 55% of plant and algal growth tests, respectively.

Magnitude and Geographic Extent of Effects

Most mines (25/29 or 86%) assessing the magnitude and extent (M&E) of effects confirmed in the exposure area near the point of effluent discharge (near-field area) observed one or more of the same effects in the exposure area farther from the point of effluent discharge (far-field area). Half of the mines (14/25 or 56%) assessing the M&E of multiple confirmed effects (near-field area) observed the same multiple effects in far-field areas. Near-field confirmed effects on fish and fish habitat were also observed in far-field areas 31% and 55% of the time, respectively. More than 50% of the time, fish effects observed in far-field areas were smaller in magnitude than the confirmed near-field effects. The magnitude of effects on fish habitat observed in far-field areas was similar to the magnitude of near-field confirmed effects, which is indicative of a greater risk to the environment. There was no relationship between the occurrence of effects in far-field areas and the distance of those far-field areas from the mine effluent discharge points.

Causes of Effects

Most studies on the cause of effects examined multiple confirmed effects. About half of the 35 mines conducting IOC studies investigated inhibitory effects, where the indicators measured were smaller in the exposure area compared to the reference area. The remaining mines conducting IOC studies investigated stimulatory effects, where the indicators measured were larger in the exposure area than in the reference area, or a mix of inhibitory/stimulatory effects.

Of the 26 mines that had completed their IOC studies, 77% identified current mine effluent as a primary or possible contributing cause of effects. Two mines identified effluent substances as a cause, but did not indicate if current mine effluent was the source, and four mines indicated that effects were caused by non-mine-related factors.

The following effluent substances were identified as possible causes of observed effects:

- major ions
- metals
- nitrogen compounds (ammonia and nitrate)
- total suspended solids
- phosphorus
- selenium

Major ions and phosphorus tended to be associated with stimulatory effects, whereas metals, selenium and total suspended solids were more often associated with inhibitory effects. Nitrogen compounds were associated with both stimulatory and inhibitory effects.

Potential causes identified for further investigation by the nine mines conducting ongoing IOC studies included nitrogen compounds, selenium, and major ions in mine effluent, metals in mine effluent and/or sediment, and non-mine-related factors.

## 7.0 Glossary

**Benthic invertebrate community –** The varied populations of small animals (excluding fish and other vertebrates) that live in or on bottom sediment or a rocky substrate and that provide food resources for fish. Measuring changes in benthic invertebrate communities helps to understand changes in aquatic habitats and provides an evaluation of the aquatic food resources available to fish and an indication of change in water quality.

**Body Condition –** A measure of the physical condition of fish that describes the relationship between body weight and body length; condition essentially measures how "fat" fish are in each area investigated.

**Control/impact design –** A study design consisting of no less than one reference area, usually upstream from the mine or situated in a different watershed (not exposed to mine effluent), and one exposure area or a series of exposure areas, often downstream from the mine (exposed to mine effluent).

**Critical effect size (CES) –** A threshold above which an effect may be indicative of a higher risk to the environment.

**Density –** The total number of individuals of all taxonomic categories collected at a sampling station, expressed per unit area.

**Effect –** In the context of the MMER, an effect on fish or the benthic invertebrate community is a statistically significant difference between measurements taken from the exposure area and from the reference area or measurements taken from sampling areas that have gradually decreasing effluent concentrations with increasing distance from a final discharge point. An effect on fish tissue is defined as measurements of concentrations of total mercury that exceed 0.5 µg/g wet weight in fish tissue taken in an exposure area and that are statistically higher than the concentrations of total mercury in fish tissue taken in a reference area.

**Evenness index –** A measure of how evenly individuals are distributed among the different taxa. This measure helps to evaluate changes in the relative abundance of taxa.

**Exposure area –** All fish habitat and waters frequented by fish that are exposed to effluent.

**Gradient design –** A study design in which sampling is done along a gradient of decreasing effluent concentration, starting with exposure areas close to the mine and progressing towards less exposed areas farther from the mine.

**Inhibitory effect –** Refers to a situation where the indicator being measured is smaller in the exposure area than in the reference area.

**Liver condition (relative liver weight)** – A measure of fish energy storage and/or response to toxicant exposure that describes the relationship between liver weight and body weight.

**Reference area –** Water frequented by fish that is not exposed to effluent and that has fish habitat that is as similar as possible to that of the exposure area.

**Reference condition approach (RCA) –** A study design involving the assessment of a large number of sites in reference areas for comparison to test (exposure area) sites.

**Relative gonad weight** – A measure of fish reproductive investment that describes the relationship between gonad weight and body weight.

**Similarity Index –** An index that measures the degree of difference in community structure (especially community taxonomic composition) between two sites. The higher the value, the greater the difference. The index is used to evaluate the amount of similarity between benthic invertebrate communities at different sites relative to reference conditions.

**Stimulatory effects** – Refers to a situation where the indicators being measured are larger in the exposure area than in the reference area.

**Sublethal toxicity (SLT) tests –** In the context of EEM, sublethal toxicity tests measure the effluent concentration for which a given effect level is observed on the organisms in a laboratory setting. Stimulation is sometimes observed instead of inhibition. Stimulation refers to an increase in the growth of the organisms relative to controls after effluent exposure. A sublethal toxicity test measures what is detrimental to the organism (e.g., effects on growth or reproduction), but below the level that directly causes death within the test period.

**Taxon** (plural taxa) **–** A taxonomic group into which an organism is classified based on structural similarities and evolutionary relationships with other organisms. Traditionally these groups are arranged hierarchically into species, genus, family, order, class, phylum, etc.

**Taxon richness –** The total number of different taxonomic categories collected in a sample or at a sampling station (e.g., number of species, number of families).

**Weight-at-age –** A measurement of the rate of growth of fish described by the relationship of size (weight) to age. Over the entire life span of a fish, the rate of increase in size may decline as the fish ages.

## 8.0 References

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**Appendix A:** Metal Mines Subject to the *Metal Mining Effluent Regulations* in 2013

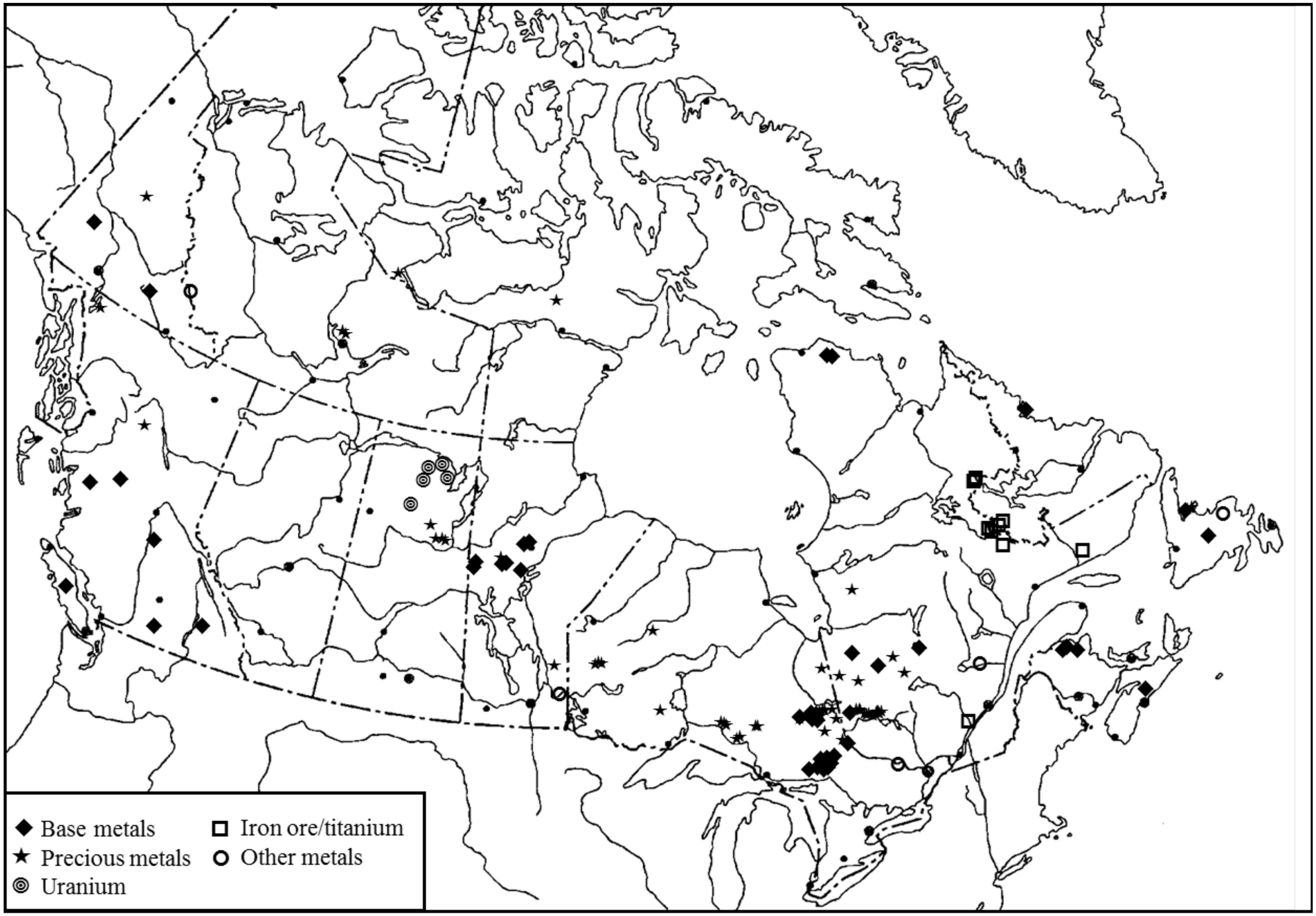


**Figure A1.** Geographic location of metal mines subject to the *Metal Mining Effluent Regulations* in 2013

## **Appendix B:** Effect Indicators, Critical Effect Sizes and Studies Conducted

**Table B1.** Fish population effect indicators and endpoints for different study designs

| **Fish Population Effect Indicators** | **Fish Population Effect Endpoints** | | |
|---|---|---|---|
| | Lethal sampling design | Non-lethal sampling design | Alternative design* |
| **Survival** | Age<br>Age frequency distribution | Length frequency distribution | Length frequency analysis |
| **Growth (energy use)** | Body weight-at-age | Weight of young-of-the-year (YOY) (age 0) at end of growth period<br>Length of YOY (age 0) at end of growth period | Whole animal wet weight<br>Shell length and width<br>Soft tissue fresh weight |
| **Reproduction (energy use)** | Gonad weight-at-body weight | Relative abundance of YOY (% composition of YOY) | Gonad weight-at-body weight (gonadosomatic index [GSI]) |
| **Body Condition (energy storage)** | Body weight-at-length | Body weight-at-length | Weight (whole animal dry weight, dry shell or soft tissue) related to shell length |
| **Liver Condition (energy storage)** | Liver weight-at-body weight | | |

*Alternative monitoring designs are described in the Metal Mining Technical Guidance for EEM (Environment Canada 2012a).

**Table B2.** Fish Habitat effect indicators

| **Fish Habitat Effect Indicators** |
|---|
| Total density (number of animals per unit area) |
| Evenness index (distribution of numbers of individuals among types of organisms) |
| Taxon richness (number of different types of organisms) |
| Similarity index (resemblance in invertebrate community structure between exposed and reference areas[21]) |

[21] The similarity index most commonly used by mines is in fact a dissimilarity index that measures the difference between two areas in order to report on benthic invertebrate community structure: the Bray-Curtis Index.

**Table B3.** Critical effect sizes (CESs)

| Fish Effect Endpoints | CES | Benthic Invertebrate Effect Endpoints | CES |
|---|---|---|---|
| Body weight-at-length | ± 10% | Total density | ± 2SD |
| Relative liver weight | ± 25% | Taxon richness | ± 2SD |
| Relative gonad weight | ± 25% | Evenness index | ± 2SD |
| Weight-at-age | ± 25% | Similarity index (Bray-Curtis) | ≥2SD |
| Age | ± 25% | | |

Note: Differences in fish population effect endpoints are expressed as percent (%) of reference mean, while differences in benthic invertebrate effect endpoints are expressed as multiples of within-reference-area standard deviations (SDs).

**Table B4.** Number and design of biological monitoring studies conducted or attempted by mines (number of mines conducting studies in parentheses)

| Biological Monitoring Study Design | 1st Study* | 2nd Study | 3rd Study | 4th Study | Total Studies Conducted |
|---|---|---|---|---|---|
| **Fish Habitat** | | | | | |
| Control Impact and Multiple C/I | 109 (114) | 73 (77) | 27 (28) | 4 (4) | 213 |
| Gradient | 3 (3) | 2 (2) | 0 | 0 | 5 |
| Reference Condition Approach | 1 (3) | 1 (3) | 0 | 0 | 2 |
| *Magnitude and Geographic Extent*** | | | 11 (13) | 3 (3) | 14 |
| *Investigation of Cause* | | | 10 (13) | 21 (25) | 31 |
| **Fish population** ** | | | | | |
| Lethal (only) | 66 (69) | 36 (38) | 17 (17) | 3 (3) | 122 |
| Non-lethal (only) | 24 (24) | 17 (17) | 5 (5) | 0 (0) | 46 |
| Lethal and non-lethal | 12 (14) | 17 (19) | 5 (6) | 2 (2) | 36 |
| Alternative | 4 (5) | 5 (7) | 2 (2) | 0 (0) | 11 |
| *Magnitude and Geographic Extent* | | | 9 (11) | 2 (2) | 11 |
| *Investigation of Cause* | | | 7 (7) | 16 (18) | 23 |
| **Use of fisheries resources** | | | | | |
| Fish tissue | 30 (30) | 25 (26) | 11 (12) | 1 (1) | 67 |

Note: some studies were conducted jointly by two or more mines;
* includes five mines considered to have completed the first study twice (two had a change in the location of the final discharge point, one had an important change in water treatment and two had to relaunch the assessment of effects as the reference and exposure areas sampled in the previous studies differed in terms of habitat type).
** Seven mines were not required to assess the fish component in at least one biological monitoring study because the proportion of effluent in the receiving environment was lower than 1% at a distance of 250 metres from the final discharge point.

**Appendix C:** Mine-by-Mine Results of Studies Assessing Potential Effects

**Table C1.** Mine-by-mine results of studies assessing potential effects on fish and fish habitat

## Legend

| | |
|---|---|
| effect ≥ CES | effect observed in one study of a magnitude ≥ CES |
| effect < CES | effect observed in one study of a magnitude < CES |
| effect of unknown magnitude | effect observed in one study of undetermined magnitude |
| absence of effect | effect not observed in one study |
| confirmed ≥ CES | similar type of effect observed in two consecutive studies of a magnitude ≥ CES |
| confirmed variable magnitude | similar type of effect observed in two consecutive studies of a magnitude ≥ CES in one study and < CES in the other study |
| confirmed < CES | similar type of effect observed in two consecutive studies of a magnitude < CES |
| confirmed unknown magnitude | similar type of effect observed in two consecutive studies of undetermined magnitude |
| confirmed absence of effect | effect not observed in two consecutive studies |
| unconfirmed effect | effect observed in one study and not observed in the other study |
| (<) | effect or confirmed effect where effect indicator is smaller in the exposure area relative to the reference area |
| (>) | effect or confirmed effect where effect indicator is larger in the exposure area relative to the reference area |
| na | sufficient data to assess effect was not available |

| | Highest Level of Effect for Fish Habitat | Density | Taxon Richness | Similarity Index | Evenness Index | Highest Level of Effect for Fish | Survival | Growth | Reproduction | Body Condition | Liver Condition | Highest Level of Effect for Fish and Fish Habitat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Base Metal Mines (includes copper, nickel, lead, zinc and molybdenum)** | | | | | | | | | | | | |
| BM1 | confirmed variable magnitude | confirmed absence of effect | confirmed absence of effect | confirmed variable magnitude | unconfirmed effect | confirmed ≥ CES | confirmed variable magnitude (<) | confirmed variable magnitude (>) | confirmed variable magnitude (>) | confirmed variable magnitude (>) | confirmed ≥ CES (>) | confirmed ≥ CES |
| BM2 | confirmed ≥ CES | confirmed absence of effect | confirmed absence of effect | confirmed ≥ CES | unconfirmed effect | unconfirmed effect | na | na | na | unconfirmed effect | na | confirmed ≥ CES |
| BM3 | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES (<) | confirmed ≥ CES | confirmed absence of effect | confirmed unknown magnitude | confirmed unknown magnitude (<) | confirmed unknown magnitude (>) | na | unconfirmed effect | na | confirmed ≥ CES |

| | Highest Level of Effect for Fish Habitat | Density | Taxon Richness | Similarity Index | Evenness Index | Highest Level of Effect for Fish | Survival | Growth | Reproduction | Body Condition | Liver Condition | Highest Level of Effect for Fish and Fish Habitat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BM4 | confirmed ≥ CES | confirmed absence of effect | confirmed ≥ CES (<) | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES | confirmed variable magnitude (>) | confirmed < CES (>) | confirmed ≥ CES (<) | confirmed variable magnitude (>) | unconfirmed effect | confirmed ≥ CES |
| BM5 | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES (<) | unconfirmed effect | na | unconfirmed effect | confirmed absence of effect | na | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | confirmed ≥ CES |
| BM6 | unconfirmed effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | na | effect ≥ CES | absence of effect | na | absence of effect | ≥ CES (>) | absence of effect | effect ≥ CES |
| BM7 | confirmed ≥ CES | confirmed absence of effect | confirmed absence of effect | confirmed ≥ CES | confirmed absence of effect | confirmed variable magnitude | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | confirmed variable magnitude (<) | confirmed ≥ CES |
| BM8 | absence of effect | absence of effect | absence of effect | absence of effect | absence of effect | effect of unknown magnitude | absence of effect | effect of unknown magnitude (>) | na | effect of unknown magnitude (>) | na | effect of unknown magnitude |
| BM9 | confirmed ≥ CES | confirmed ≥ CES (>) | confirmed absence of effect | confirmed < CES | na | confirmed unknown magnitude | na | confirmed unknown magnitude (>) | na | confirmed absence of effect | na | confirmed ≥ CES |
| BM10 | confirmed ≥ CES | confirmed absence of effect | confirmed variable magnitude (<) | unconfirmed effect | unconfirmed effect | confirmed ≥ CES | confirmed < CES (>) | confirmed ≥ CES (<) | confirmed < CES (<) | confirmed ≥ CES (<) | unconfirmed effect | confirmed ≥ CES |
| BM11 | confirmed ≥ CES | confirmed ≥ CES (>) | unconfirmed effect | unconfirmed effect | na | unconfirmed effect | confirmed absence of effect | na | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | confirmed ≥ CES |
| BM12 | effect < CES | absence of effect | absence of effect | < CES | < CES (<) | no result: study not required | | | | | | effect < CES |
| BM13 | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | confirmed ≥ CES | unconfirmed effect | unconfirmed effect | confirmed variable magnitude (>) | unconfirmed effect | confirmed ≥ CES (>) | confirmed ≥ CES |
| BM14 | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES (<) | confirmed ≥ CES | confirmed variable magnitude (<) | confirmed < CES | unconfirmed effect | unconfirmed effect | confirmed < CES (<) | confirmed < CES (<) | unconfirmed effect | confirmed ≥ CES |
| BM15 | unconfirmed effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | effect of unknown magnitude | effect of unknown magnitude (>) | effect of unknown magnitude (>) | effect of unknown magnitude (<) | effect of unknown magnitude (>) | na | unconfirmed effect |

| | Highest Level of Effect for Fish Habitat | Density | Taxon Richness | Similarity Index | Evenness Index | Highest Level of Effect for Fish | Survival | Growth | Reproduction | Body Condition | Liver Condition | Highest Level of Effect for Fish and Fish Habitat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BM16 | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES (<) | confirmed ≥ CES | confirmed ≥ CES (>) | unconfirmed effect | unconfirmed effect | na | na | unconfirmed effect | na | confirmed ≥ CES |
| BM17 | confirmed variable magnitude | unconfirmed effect | confirmed absence of effect | confirmed variable magnitude | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed variable magnitude |
| BM18 | confirmed variable magnitude | unconfirmed effect | unconfirmed effect | confirmed variable magnitude | unconfirmed effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | na | confirmed variable magnitude |
| BM19 | confirmed ≥ CES | confirmed absence of effect | confirmed absence of effect | confirmed ≥ CES | confirmed ≥ CES (<) | confirmed unknown magnitude | confirmed unknown magnitude (>) | unconfirmed effect | na | unconfirmed effect | na | confirmed ≥ CES |
| BM20 | confirmed ≥ CES | confirmed ≥ CES (>) | confirmed absence of effect | confirmed < CES | unconfirmed effect | unconfirmed effect | na | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | confirmed ≥ CES |
| BM21 | unconfirmed effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | confirmed < CES | na | na | na | confirmed < CES (>) | na | confirmed < CES |
| BM22 | confirmed variable magnitude | confirmed absence of effect | unconfirmed effect | confirmed variable magnitude | unconfirmed effect | confirmed unknown magnitude | na | na | na | confirmed unknown magnitude (>) | na | confirmed variable magnitude |
| BM23 | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect |
| BM24 | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | confirmed unknown magnitude | confirmed unknown magnitude (<) | na | na | unconfirmed effect | na | confirmed unknown magnitude |
| BM25 | confirmed variable magnitude | confirmed absence of effect | confirmed absence of effect | confirmed variable magnitude | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed variable magnitude |
| BM26 | effect < CES | < CES (<) | absence of effect | absence of effect | absence of effect | effect ≥ CES | ≥ CES (<) | na | na | na | na | effect ≥ CES |
| BM27 | confirmed ≥ CES | unconfirmed effect | confirmed absence of effect | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES | confirmed < CES (>) | confirmed ≥ CES (<) | confirmed < CES (<) | confirmed ≥ CES (<) | unconfirmed effect | confirmed ≥ CES |
| BM28 | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | no result: fish survey could not be conducted or completed | | | | | | unconfirmed effect |

| | Highest Level of Effect for Fish Habitat | Density | Taxon Richness | Similarity Index | Evenness Index | Highest Level of Effect for Fish | Survival | Growth | Reproduction | Body Condition | Liver Condition | Highest Level of Effect for Fish and Fish Habitat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BM29 | effect ≥ CES | < CES (>) | ≥ CES (<) | ≥ CES | ≥ CES (<) | effect ≥ CES | absence of effect | ≥ CES (>) | effect of unknown magnitude (>) | effect of unknown magnitude (>) | ≥ CES (>) | effect ≥ CES |
| BM30 | confirmed variable magnitude | confirmed variable magnitude (>) | confirmed < CES (>) | confirmed variable magnitude | unconfirmed effect | confirmed unknown magnitude | confirmed unknown magnitude (>) | confirmed unknown magnitude (>) | na | unconfirm ed effect | na | confirmed variable magnitude |
| BM31 | effect < CES | < CES (<) | absence of effect | absence of effect | absence of effect | effect < CES | na | na | absence of effect | < CES (<) | absence of effect | effect < CES |
| BM32 | confirmed ≥ CES | confirmed ≥ CES (>) | confirmed absence of effect | confirmed ≥ CES | unconfirmed effect | effect < CES | absence of effect | effect of unknown magnitude (>) | na | < CES (>) | na | confirmed ≥ CES |
| BM33 | confirmed variable magnitude | confirmed absence of effect | confirmed absence of effect | confirmed variable magnitude | confirmed absence of effect | confirmed < CES | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed < CES (>) | confirmed < CES (>) | confirmed variable magnitude |
| BM34 | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | na | na | na | confirmed absence of effect | na | unconfirmed effect |
| BM35 | effect ≥ CES | ≥ CES (<) | < CES (<) | ≥ CES | absence of effect | no result: study not required | | | | | | effect ≥ CES |
| BM36 | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | confirmed ≥ CES | unconfirmed effect | unconfirmed effect | confirmed ≥ CES (>) | confirmed ≥ CES (>) | confirmed ≥ CES (>) | confirmed ≥ CES |
| BM37 | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | na | na | na | confirmed absence of effect | na | confirmed absence of effect |
| BM38 | effect ≥ CES | absence of effect | absence of effect | ≥ CES | ≥ CES (>) | no result: study not required | | | | | | effect ≥ CES |
| BM39 | confirmed ≥ CES | unconfirmed effect | confirmed absence of effect | confirmed ≥ CES | confirmed absence of effect | confirmed variable magnitude | na | na | confirmed variable magnitude (<) | unconfirm ed effect | unconfirm ed effect | confirmed ≥ CES |
| BM40 | effect ≥ CES | ≥ CES (>) | absence of effect | ≥ CES | absence of effect | effect < CES | na | na | absence of effect | < CES (<) | absence of effect | effect ≥ CES |
| BM41 | effect ≥ CES | ≥ CES (<) | < CES (>) | ≥ CES | absence of effect | no result: fish survey could not be conducted or completed | | | | | | effect ≥ CES |

| | Highest Level of Effect for Fish Habitat | Density | Taxon Richness | Similarity Index | Evenness Index | Highest Level of Effect for Fish | Survival | Growth | Reproduction | Body Condition | Liver Condition | Highest Level of Effect for Fish and Fish Habitat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BM42 | effect ≥ CES | < CES (<) | < CES (<) | ≥ CES | absence of effect | effect ≥ CES | < CES (<) | ≥ CES (<) | ≥ CES (<) | < CES (>) | < CES (>) | effect ≥ CES |
| BM43 | confirmed ≥ CES | unconfirmed effect | unconfirmed effect | confirmed ≥ CES | confirmed absence of effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirm ed effect | unconfirm ed effect | confirmed ≥ CES |
| BM44 | absence of effect | absence of effect | absence of effect | absence of effect | absence of effect | effect < CES | na | na | na | < CES (<) | na | effect < CES |
| BM45 | effect of unknown magnitude | effect of unknown magnitude (<) | effect of unknown magnitude (<) | effect of unknown magnitude | na | effect of unknown magnitude | absence of effect | effect of unknown magnitude (>) | absence of effect | absence of effect | effect of unknown magnitude (>) | effect of unknown magnitude |
| **Iron Ore Mines (includes iron and titanium)** | | | | | | | | | | | | |
| FeTi1 | confirmed ≥ CES | confirmed ≥ CES (<) | confirmed ≥ CES (<) | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES (<) | confirmed variable magnitude (<) | confirmed ≥ CES (<) | unconfirm ed effect | confirmed ≥ CES |
| FeTi2 | confirmed ≥ CES | confirmed absence of effect | confirmed absence of effect | confirmed ≥ CES | confirmed absence of effect | confirmed < CES | unconfirmed effect | confirmed < CES (<) | unconfirmed effect | unconfirm ed effect | unconfirm ed effect | confirmed ≥ CES |
| FeTi3 | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | na | na | unconfirm ed effect | na | unconfirmed effect |
| FeTi4 | effect ≥ CES | absence of effect | absence of effect | ≥ CES | absence of effect | effect of unknown magnitude | absence of effect | absence of effect | absence of effect | absence of effect | effect of unknown magnitude (<) | effect ≥ CES |
| FeTi5 | confirmed variable magnitude | confirmed absence of effect | confirmed variable magnitude (<) | confirmed < CES | confirmed absence of effect | confirmed variable magnitude | unconfirmed effect | unconfirmed effect | confirmed variable magnitude (<) | unconfirm ed effect | unconfirm ed effect | confirmed variable magnitude |
| FeTi6 | effect ≥ CES | absence of effect | < CES (<) | ≥ CES | absence of effect | no result: fish survey could not be conducted or completed | | | | | | effect ≥ CES |
| FeTi7 | absence of effect | absence of effect | absence of effect | absence of effect | absence of effect | effect ≥ CES | ≥ CES (>) | effect of unknown magnitude (>) | effect of unknown magnitude (<) | effect of unknown magnitude (<) | effect of unknown magnitude (<) | effect ≥ CES |
| **Precious Metals Mines (includes gold, silver and platinum group metals)** | | | | | | | | | | | | |
| PM1 | confirmed ≥ CES | confirmed absence of effect | unconfirmed effect | confirmed ≥ CES | confirmed ≥ CES (>) | confirmed ≥ CES | confirmed variable magnitude (<) | confirmed ≥ CES (>) | unconfirmed effect | confirmed < CES (<) | confirmed variable magnitude (>) | confirmed ≥ CES |

| | Highest Level of Effect for Fish Habitat | Density | Taxon Richness | Similarity Index | Evenness Index | Highest Level of Effect for Fish | Survival | Growth | Reproduction | Body Condition | Liver Condition | Highest Level of Effect for Fish and Fish Habitat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PM2 | confirmed ≥ CES | confirmed variable magnitude (<) | confirmed ≥ CES (<) | unconfirmed effect | unconfirmed effect | confirmed ≥ CES | confirmed ≥ CES (>) | unconfirmed effect | confirmed variable magnitude (<) | confirmed ≥ CES (<) | confirmed ≥ CES (<) | confirmed ≥ CES |
| PM3 | unconfirmed effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | confirmed ≥ CES | confirmed absence of effect | unconfirmed effect | confirmed ≥ CES (>) | unconfirmed effect | confirmed ≥ CES (>) | confirmed ≥ CES |
| PM4 | confirmed ≥ CES | unconfirmed effect | confirmed absence of effect | confirmed ≥ CES | confirmed absence of effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | confirmed ≥ CES |
| PM5 | confirmed < CES | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | confirmed < CES (>) | effect ≥ CES | ≥ CES (<) | ≥ CES (>) | ≥ CES (>) | < CES (>) | ≥ CES (>) | confirmed < CES |
| PM6 | effect ≥ CES | ≥ CES (<) | absence of effect | < CES | absence of effect | effect ≥ CES | effect of unknown magnitude (>) | na | na | ≥ CES (>) | < CES (<) | effect ≥ CES |
| PM7 | confirmed ≥ CES | unconfirmed effect | unconfirmed effect | confirmed ≥ CES | unconfirmed effect | confirmed < CES | unconfirmed effect | unconfirmed effect | confirmed < CES (>) | unconfirmed effect | unconfirmed effect | confirmed ≥ CES |
| PM8 | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | effect of unknown magnitude | effect of unknown magnitude (>) | absence of effect | absence of effect | effect of unknown magnitude (<) | effect of unknown magnitude (>) | unconfirmed effect |
| PM9 | unconfirmed effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | na | unconfirmed effect | unconfirmed effect | unconfirmed effect |
| PM10 | unconfirmed effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | na | unconfirmed effect | unconfirmed effect | unconfirmed effect |
| PM11 | confirmed ≥ CES | confirmed variable magnitude (<) | confirmed ≥ CES (<) | unconfirmed effect | unconfirmed effect | confirmed ≥ CES | confirmed ≥ CES (>) | confirmed variable magnitude (<) | confirmed variable magnitude (<) | confirmed ≥ CES (<) | confirmed ≥ CES (<) | confirmed ≥ CES |
| PM12 | effect ≥ CES | absence of effect | absence of effect | ≥ CES | absence of effect | effect < CES | < CES (<) | absence of effect | absence of effect | absence of effect | absence of effect | effect ≥ CES |
| PM13 | confirmed ≥ CES | confirmed ≥ CES (>) | unconfirmed effect | confirmed ≥ CES | confirmed ≥ CES (<) | confirmed < CES | unconfirmed effect | confirmed < CES (<) | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed ≥ CES |
| PM14 | confirmed variable magnitude | confirmed absence of effect | confirmed absence of effect | confirmed variable magnitude | unconfirmed effect | confirmed < CES | unconfirmed effect | unconfirmed effect | confirmed < CES (<) | confirmed < CES (<) | unconfirmed effect | confirmed variable magnitude |

| | Highest Level of Effect for Fish Habitat | Density | Taxon Richness | Similarity Index | Evenness Index | Highest Level of Effect for Fish | Survival | Growth | Reproduction | Body Condition | Liver Condition | Highest Level of Effect for Fish and Fish Habitat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PM15 | unconfirmed effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | effect of unknown magnitude | effect of unknown magnitude (>) | effect of unknown magnitude (>) | na | effect of unknown magnitude (<) | na | unconfirmed effect |
| PM16 | confirmed ≥ CES | unconfirmed effect | confirmed variable magnitude (<) | confirmed ≥ CES | unconfirmed effect | confirmed variable magnitude | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirm ed effect | confirmed variable magnitude (>) | confirmed ≥ CES |
| PM17 | unconfirmed effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | effect < CES | absence of effect | absence of effect | absence of effect | absence of effect | < CES (<) | unconfirmed effect |
| PM18 | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | na | na | na | unconfirm ed effect | na | unconfirmed effect |
| PM19 | unconfirmed effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed absence of effect | na | unconfirmed effect |
| PM20 | confirmed variable magnitude | unconfirmed effect | confirmed variable magnitude (>) | unconfirmed effect | confirmed absence of effect | effect of unknown magnitude | absence of effect | effect of unknown magnitude (<) | na | effect of unknown magnitude (<) | na | confirmed variable magnitude |
| PM21 | confirmed variable magnitude | confirmed variable magnitude (>) | confirmed absence of effect | confirmed variable magnitude | unconfirmed effect | confirmed ≥ CES | confirmed variable magnitude (<) | confirmed ≥ CES (>) | unconfirmed effect | confirmed < CES (>) | unconfirm ed effect | confirmed ≥ CES |
| PM22 | effect ≥ CES | ≥ CES (<) | absence of effect | absence of effect | absence of effect | effect ≥ CES | absence of effect | < CES (<) | absence of effect | absence of effect | ≥ CES (>) | effect ≥ CES |
| PM23 | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | effect of unknown magnitude | effect of unknown magnitude (<) | absence of effect | absence of effect | effect of unknown magnitude (>) | na | unconfirmed effect |
| PM24 | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | effect ≥ CES | ≥ CES (>) | < CES (>) | < CES (<) | ≥ CES (>) | ≥ CES (<) | unconfirmed effect |
| PM25 | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed < CES | unconfirmed effect | unconfirmed effect | confirmed absence of effect | confirmed < CES (<) | unconfirm ed effect | confirmed < CES |
| PM26 | confirmed variable magnitude | unconfirmed effect | confirmed absence of effect | confirmed variable magnitude | unconfirmed effect | confirmed ≥ CES | confirmed ≥ CES (<) | confirmed absence of effect | confirmed ≥ CES (<) | confirmed ≥ CES (<) | unconfirm ed effect | confirmed ≥ CES |

| | Highest Level of Effect for Fish Habitat | Density | Taxon Richness | Similarity Index | Evenness Index | Highest Level of Effect for Fish | Survival | Growth | Reproduction | Body Condition | Liver Condition | Highest Level of Effect for Fish and Fish Habitat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PM27 | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect |
| PM28 | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES (<) | confirmed ≥ CES | confirmed ≥ CES (>) | confirmed ≥ CES | confirmed ≥ CES (>) | confirmed ≥ CES (>) | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed ≥ CES |
| PM29 | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | confirmed variable magnitude | na | na | na | confirmed variable magnitude (<) | na | confirmed variable magnitude |
| PM30 | effect ≥ CES | absence of effect | absence of effect | ≥ CES | absence of effect | confirmed < CES | confirmed absence of effect | unconfirmed effect | unconfirmed effect | confirmed < CES (<) | unconfirmed effect | confirmed < CES |
| PM31 | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | confirmed variable magnitude | unconfirmed effect | confirmed unknown magnitude (<) | confirmed variable magnitude (>) | confirmed unknown magnitude (<) | unconfirmed effect | confirmed variable magnitude |
| PM32 | confirmed variable magnitude | confirmed absence of effect | confirmed variable magnitude (<) | confirmed variable magnitude | unconfirmed effect | confirmed variable magnitude | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed variable magnitude (>) | unconfirmed effect | confirmed variable magnitude |
| PM33 | confirmed ≥ CES | confirmed absence of effect | unconfirmed effect | confirmed ≥ CES | confirmed absence of effect | no result: fish survey could not be conducted or completed | | | | | | confirmed ≥ CES |
| PM34 | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | na | unconfirmed effect | unconfirmed effect | unconfirmed effect |
| PM35 | confirmed ≥ CES | confirmed ≥ CES (>) | confirmed absence of effect | confirmed ≥ CES | confirmed absence of effect | confirmed ≥ CES | confirmed < CES (>) | confirmed unknown magnitude (<) | unconfirmed effect | confirmed ≥ CES (<) | confirmed variable magnitude (<) | confirmed ≥ CES |
| PM36 | confirmed ≥ CES | confirmed ≥ CES (<) | confirmed ≥ CES (<) | confirmed variable magnitude | confirmed absence of effect | confirmed unknown magnitude | confirmed unknown magnitude (>) | confirmed unknown magnitude (<) | na | confirmed unknown magnitude (<) | na | confirmed ≥ CES |
| PM37 | effect ≥ CES | < CES (<) | absence of effect | ≥ CES | ≥ CES (>) | absence of effect | absence of effect | absence of effect | absence of effect | absence of effect | absence of effect | effect ≥ CES |
| PM38 | effect ≥ CES | absence of effect | absence of effect | ≥ CES | absence of effect | effect ≥ CES | < CES (<) | absence of effect | ≥ CES (<) | absence of effect | ≥ CES (<) | effect ≥ CES |
| PM39 | unconfirmed effect | unconfirmed effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | no result: study not required | | | | | | unconfirmed effect |
| PM40 | effect ≥ CES | ≥ CES (>) | absence of | ≥ CES | < CES (<) | effect ≥ CES | < CES (>) | ≥ CES (<) | < CES (<) | ≥ CES (>) | ≥ CES (>) | effect ≥ CES |

| | Highest Level of Effect for Fish Habitat | Density | Taxon Richness | Similarity Index | Evenness Index | Highest Level of Effect for Fish | Survival | Growth | Reproduction | Body Condition | Liver Condition | Highest Level of Effect for Fish and Fish Habitat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | effect | | | | | | | | | |
| PM41 | confirmed ≥ CES | unconfirmed effect | confirmed absence of effect | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES (>) | confirmed variable magnitude (>) | confirmed < CES (>) | confirmed < CES (>) | confirmed ≥ CES |
| PM42 | effect ≥ CES | absence of effect | absence of effect | ≥ CES | absence of effect | effect ≥ CES | absence of effect | ≥ CES (>) | absence of effect | ≥ CES (>) | < CES (>) | effect ≥ CES |
| PM43 | effect ≥ CES | absence of effect | absence of effect | ≥ CES | < CES (>) | effect of unknown magnitude | na | na | na | effect of unknown magnitude (>) | na | effect ≥ CES |
| PM44 | effect < CES | absence of effect | < CES (<) | absence of effect | absence of effect | effect ≥ CES | effect of unknown magnitude (>) | effect of unknown magnitude (>) | absence of effect | ≥ CES (>) | na | effect ≥ CES |
| PM45 | absence of effect | absence of effect | absence of effect | absence of effect | absence of effect | absence of effect | absence of effect | na | na | absence of effect | na | absence of effect |
| PM46 | confirmed ≥ CES | unconfirmed effect | unconfirmed effect | confirmed ≥ CES | confirmed absence of effect | effect ≥ CES | ≥ CES (>) | < CES (<) | ≥ CES (>) | < CES (<) | < CES (<) | confirmed ≥ CES |
| PM47 | effect ≥ CES | ≥ CES (<) | ≥ CES (<) | ≥ CES | absence of effect | effect ≥ CES | absence of effect | absence of effect | absence of effect | effect of unknown magnitude (<) | ≥ CES (<) | effect ≥ CES |
| PM48 | effect ≥ CES | absence of effect | absence of effect | ≥ CES | absence of effect | effect ≥ CES | < CES (<) | < CES (<) | absence of effect | ≥ CES (<) | absence of effect | effect ≥ CES |
| PM49 | effect ≥ CES | ≥ CES (>) | absence of effect | ≥ CES | ≥ CES (<) | effect ≥ CES | ≥ CES (>) | effect of unknown magnitude (>) | effect of unknown magnitude (>) | ≥ CES (>) | < CES (<) | effect ≥ CES |
| PM50 | effect < CES | < CES (<) | absence of effect | < CES | absence of effect | effect ≥ CES | absence of effect | < CES (<) | < CES (<) | < CES (>) | ≥ CES (>) | effect ≥ CES |
| PM51 | absence of effect | absence of effect | absence of effect | absence of effect | absence of effect | effect < CES | absence of effect | na | < CES (<) | absence of effect | absence of effect | effect < CES |
| PM52 | absence of effect | absence of effect | absence of effect | absence of effect | absence of effect | no result: study not required | | | | | | absence of effect |

| | Highest Level of Effect for Fish Habitat | Density | Taxon Richness | Similarity Index | Evenness Index | Highest Level of Effect for Fish | Survival | Growth | Reproduction | Body Condition | Liver Condition | Highest Level of Effect for Fish and Fish Habitat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PM53 | effect < CES | < CES (>) | absence of effect | < CES | < CES (<) | effect ≥ CES | absence of effect | ≥ CES (<) | effect of unknown magnitude (>) | < CES (>) | < CES (>) | effect ≥ CES |
| **Uranium Mines** | | | | | | | | | | | | |
| U1 | confirmed ≥ CES | confirmed ≥ CES (<) | confirmed ≥ CES (<) | confirmed ≥ CES | unconfirmed effect | confirmed variable magnitude | unconfirmed effect | unconfirmed effect | unconfirmed effect | confirmed variable magnitude (<) | confirmed < CES (<) | confirmed ≥ CES |
| U2 | confirmed ≥ CES | unconfirmed effect | confirmed absence of effect | confirmed ≥ CES | confirmed absence of effect | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES (>) | unconfirmed effect | unconfirm ed effect | confirmed ≥ CES (<) | confirmed ≥ CES |
| U3 | confirmed ≥ CES | confirmed ≥ CES (>) | confirmed < CES (>) | confirmed variable magnitude | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirmed effect | unconfirm ed effect | unconfirm ed effect | confirmed ≥ CES |
| U4 | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | confirmed ≥ CES | unconfirmed effect | confirmed unknown magnitude (>) | unconfirmed effect | confirmed variable magnitude (>) | na | confirmed ≥ CES |
| U5 | confirmed ≥ CES | confirmed ≥ CES (>) | confirmed variable magnitude (>) | confirmed ≥ CES | confirmed absence of effect | confirmed ≥ CES | confirmed absence of effect | confirmed ≥ CES (>) | unconfirmed effect | unconfirm ed effect | confirmed ≥ CES (>) | confirmed ≥ CES |
| U6 | effect ≥ CES | ≥ CES (<) | ≥ CES (<) | ≥ CES | ≥ CES (>) | effect of unknown magnitude | effect of unknown magnitude (<) | effect of unknown magnitude (<) | effect of unknown magnitude (>) | effect of unknown magnitude (<) | absence of effect | effect ≥ CES |
| **Other Metal Mines (includes tungsten, tantalum, niobium and magnesium)** | | | | | | | | | | | | |
| O1 | confirmed ≥ CES | unconfirmed effect | unconfirmed effect | confirmed variable magnitude | confirmed ≥ CES (>) | confirmed absence of effect | na | na | na | confirmed absence of effect | na | confirmed ≥ CES |
| O2 | unconfirmed effect | confirmed absence of effect | confirmed absence of effect | unconfirmed effect | confirmed absence of effect | effect of unknown magnitude | effect of unknown magnitude (>) | effect of unknown magnitude (>) | na | absence of effect | na | unconfirmed effect |
| O3 | confirmed ≥ CES | unconfirmed effect | confirmed ≥ CES (<) | confirmed ≥ CES | confirmed ≥ CES (<) | confirmed variable magnitude | confirmed variable magnitude (<) | unconfirmed effect | confirmed < CES (>) | unconfirm ed effect | unconfirm ed effect | confirmed ≥ CES |
| O4 | confirmed ≥ CES | confirmed ≥ CES (>) | unconfirmed effect | confirmed ≥ CES | confirmed absence of effect | no result: study not required | | | | | | confirmed ≥ CES |

**Appendix D:** Fish Tissue Mean Total Mercury Concentrations per Mine

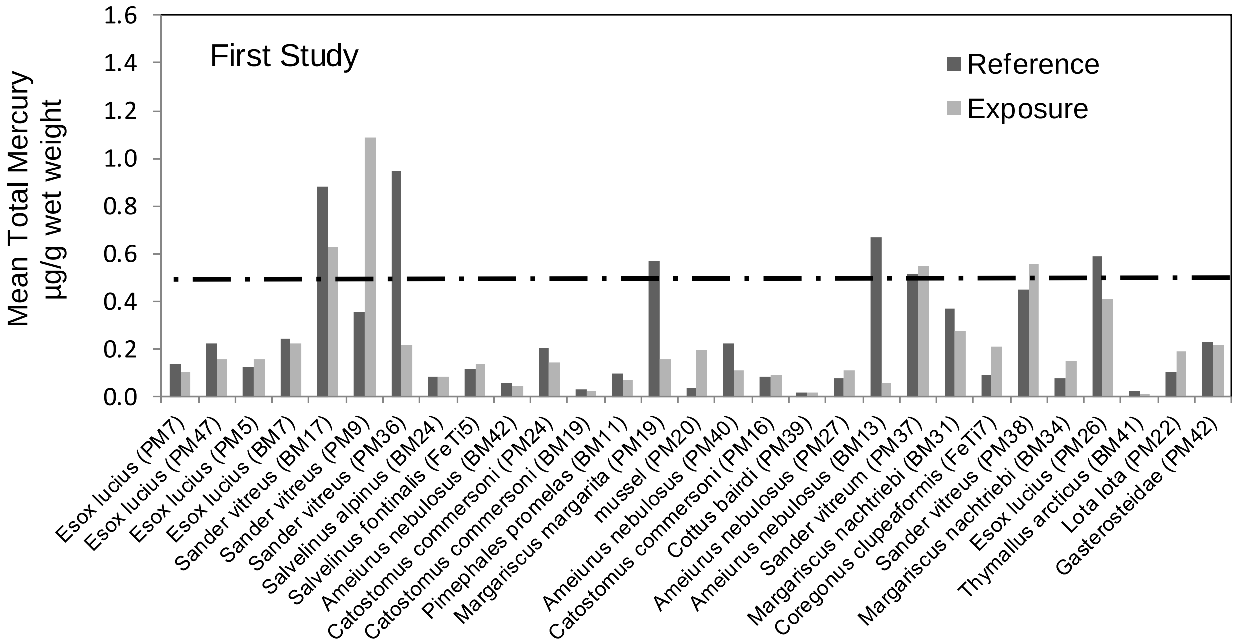


**Figure D1.** Mean total mercury in fish tissue for reference and exposure fish sampled during the mine's first EEM biological monitoring study.
Note: The dashed line represents the MMER effect level of 0.50 µg/g.

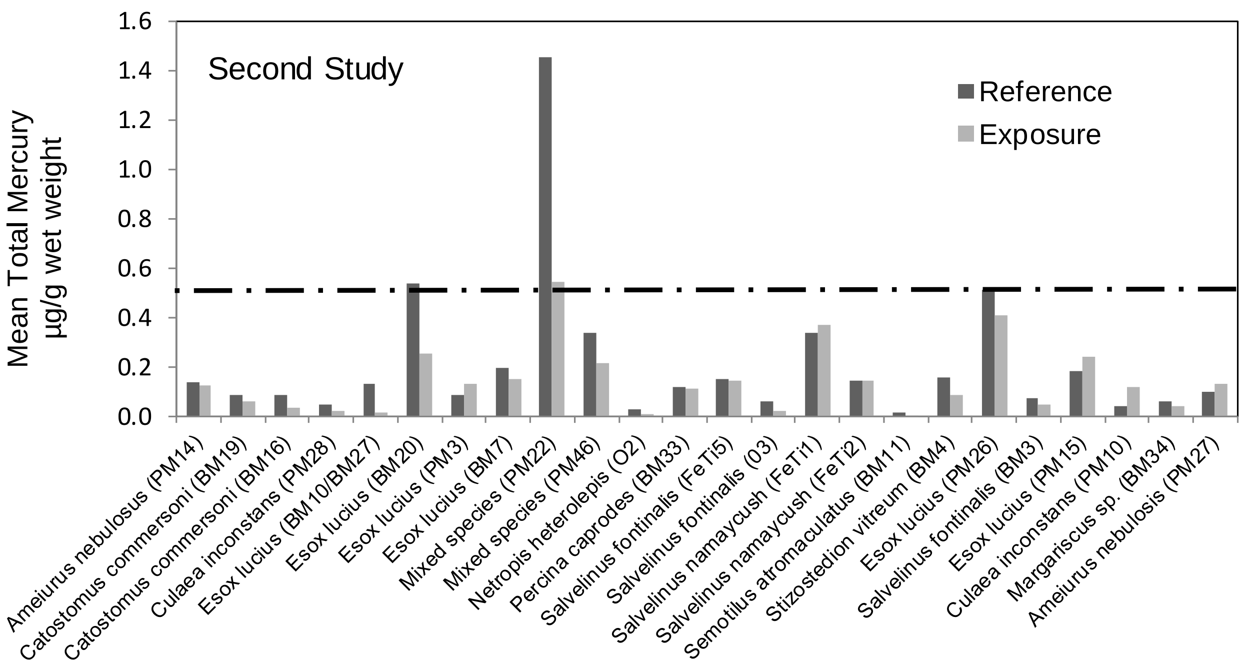


**Figure D2.** Mean total mercury in fish tissue for reference and exposure fish sampled during the mine's second EEM biological monitoring study.
Note: The dashed line represents the MMER effect level of 0.50 µg/g

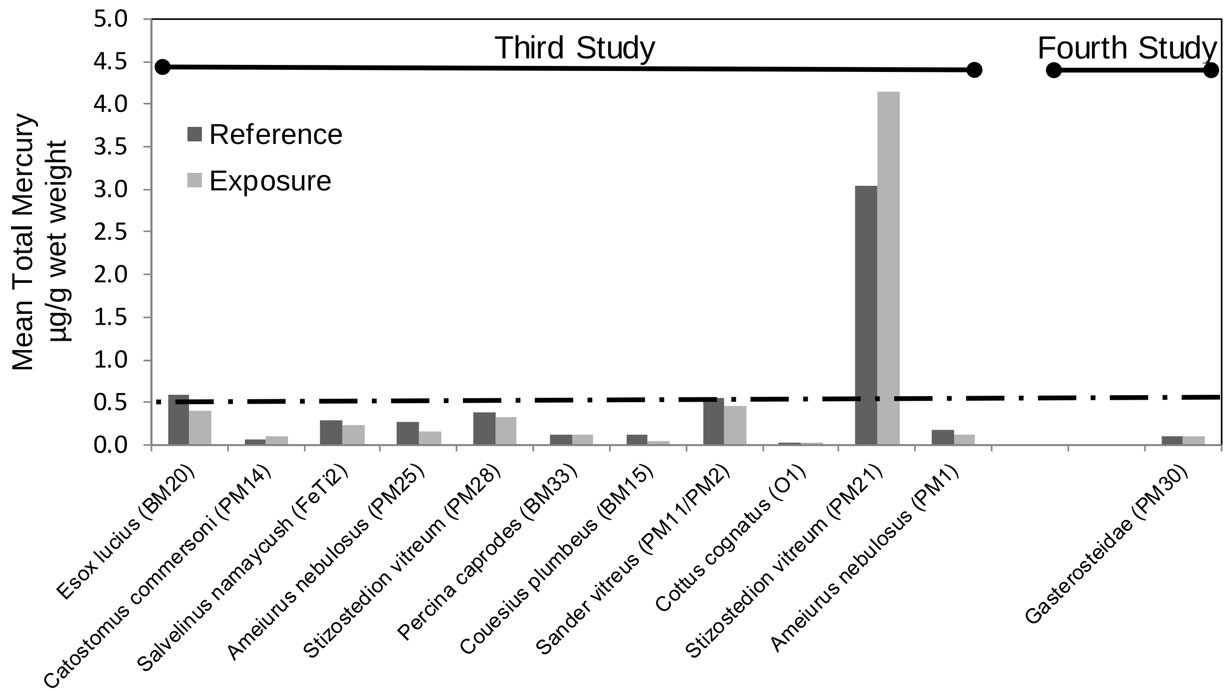


**Figure D3.** Mean total mercury in fish tissue for reference and exposure fish sampled during the mine's third and fourth EEM biological monitoring study.
Note: The dashed line represents the MMER effect level of 0.50 µg/g.

**Appendix E:** Trends in Sublethal Toxicity

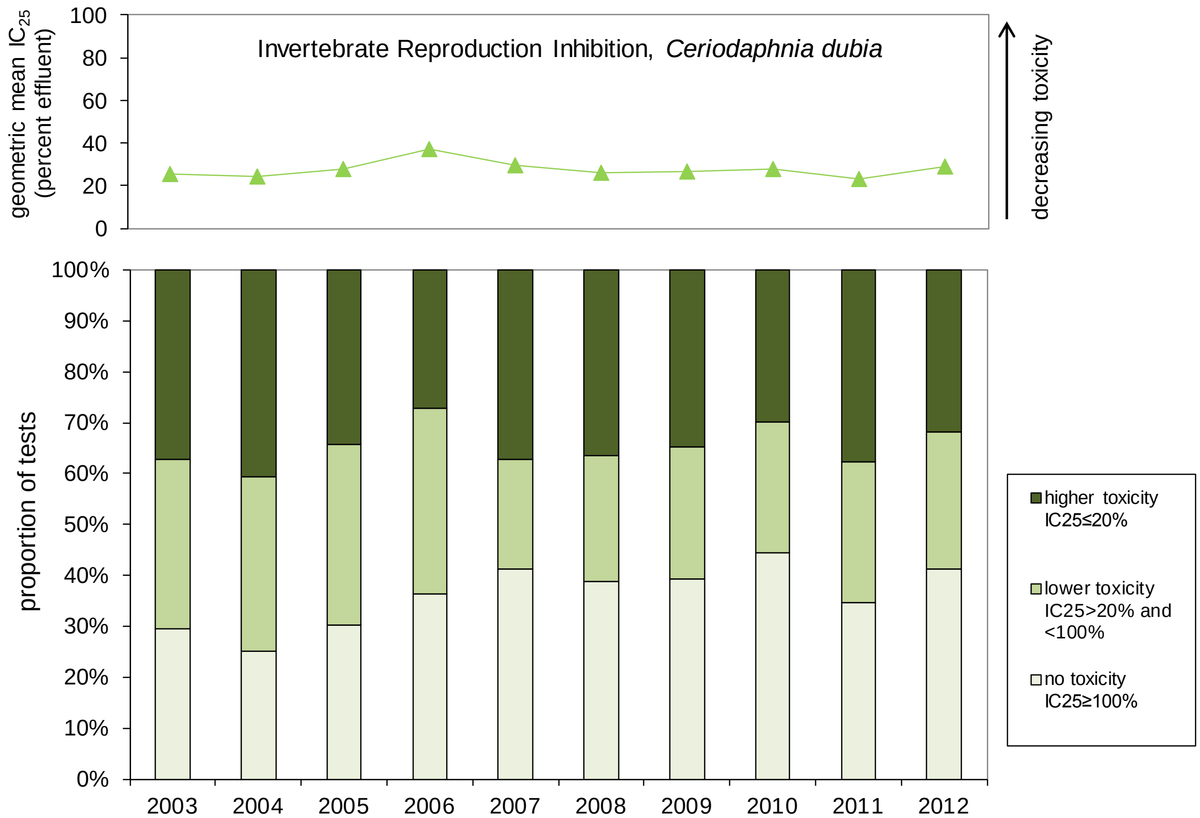


**Figure E1.** Geometric mean $IC_{25}$ (percent effluent on a volume basis) and proportion of tests in each sublethal toxicity category per year for the invertebrate reproduction inhibition test using *Ceriodaphnia dubia*

Note: The number of tests conducted each year ranged from 121 to 155.

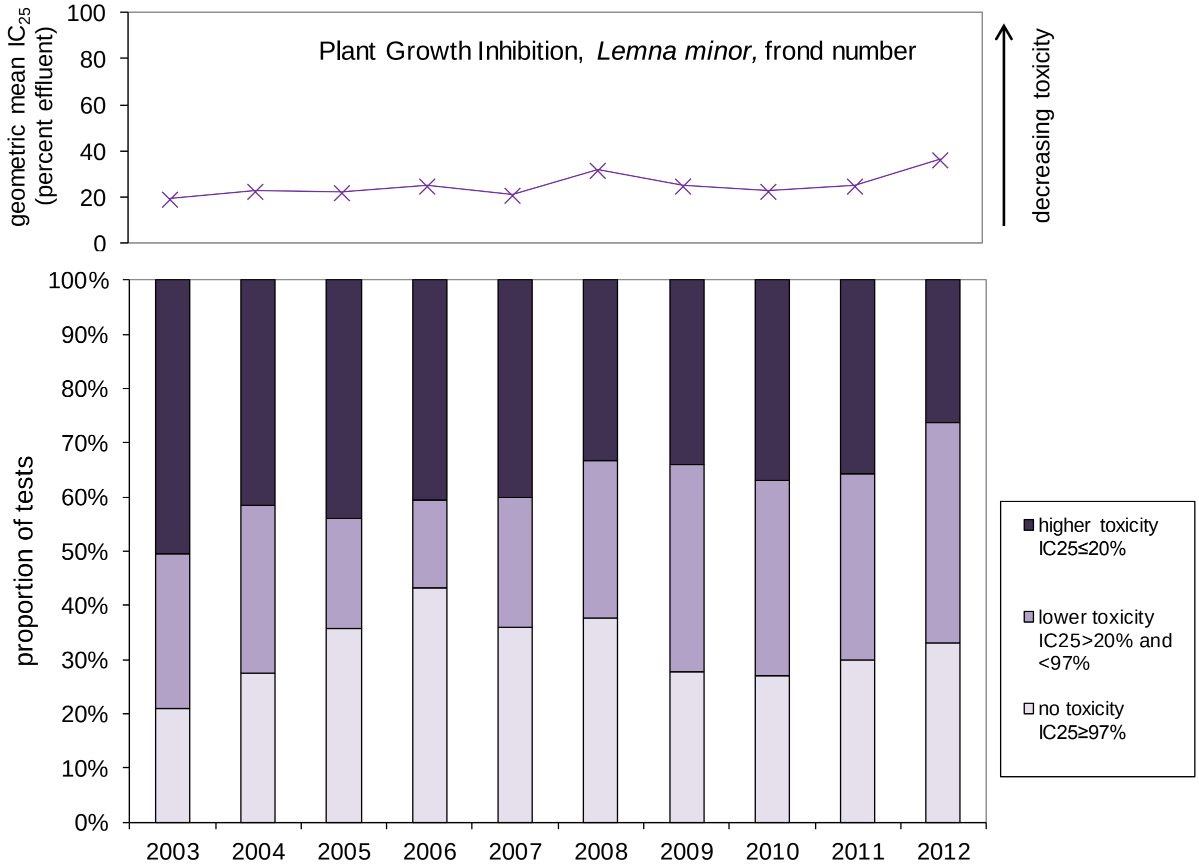


**Figure E2.** Geometric mean $IC_{25}$ (percent effluent on a volume basis) and proportion of tests in each sublethal toxicity category each year for the plant growth inhibition test using *Lemna minor* frond number

Note: The number of tests conducted each year ranged from 116 to 145.

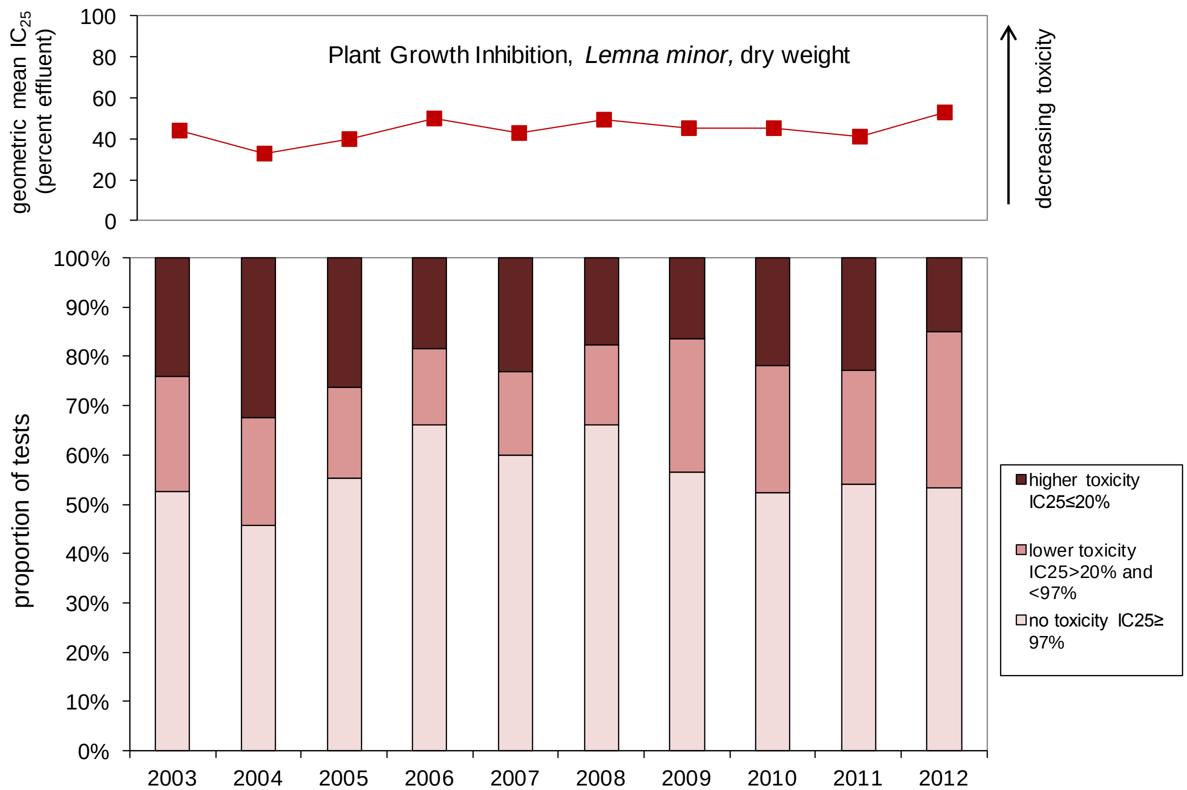


**Figure E3.** Geometric mean $IC_{25}$ (percent effluent on a volume basis) and proportion of tests in each sublethal toxicity category per year for the plant growth inhibition test using *Lemna minor* dry weight

Note: The number of tests conducted each year ranged from 117 to 142.

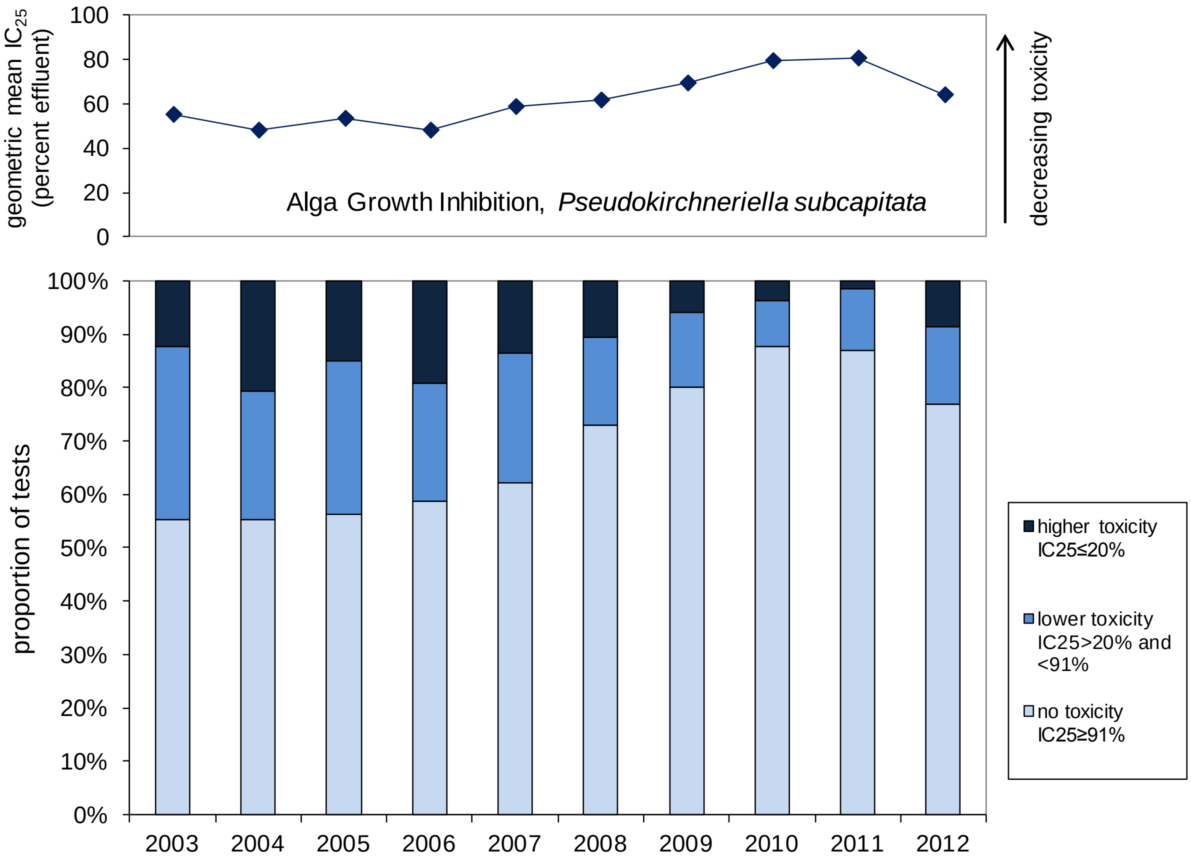


**Figure E4.** Geometric mean $IC_{25}$ (percent effluent on a volume basis) and proportion of tests in each sublethal toxicity category each year for the alga growth inhibition test using *Pseudokirchneriella subcapitata*

Note: The number of tests conducted each year ranged from 119 to 152.

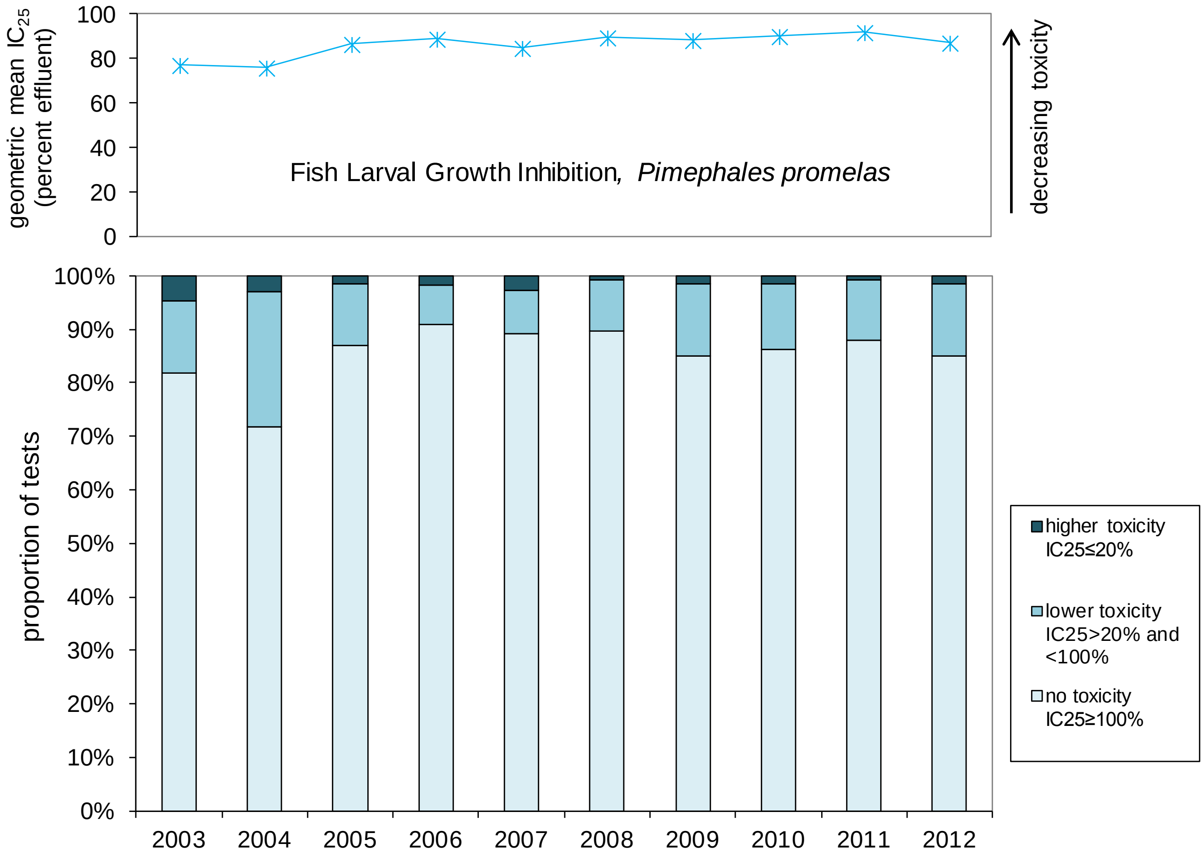


**Figure E5.** Geometric mean $IC_{25}$ (percent effluent on a volume basis) and proportion of tests in each sublethal toxicity category each year for the fish larval growth inhibition test using *Pimephales promelas*

Note: The number of tests conducted each year ranged from 111 to 140.

**Appendix F:** Trends in Sublethal Toxicity for Ore Types

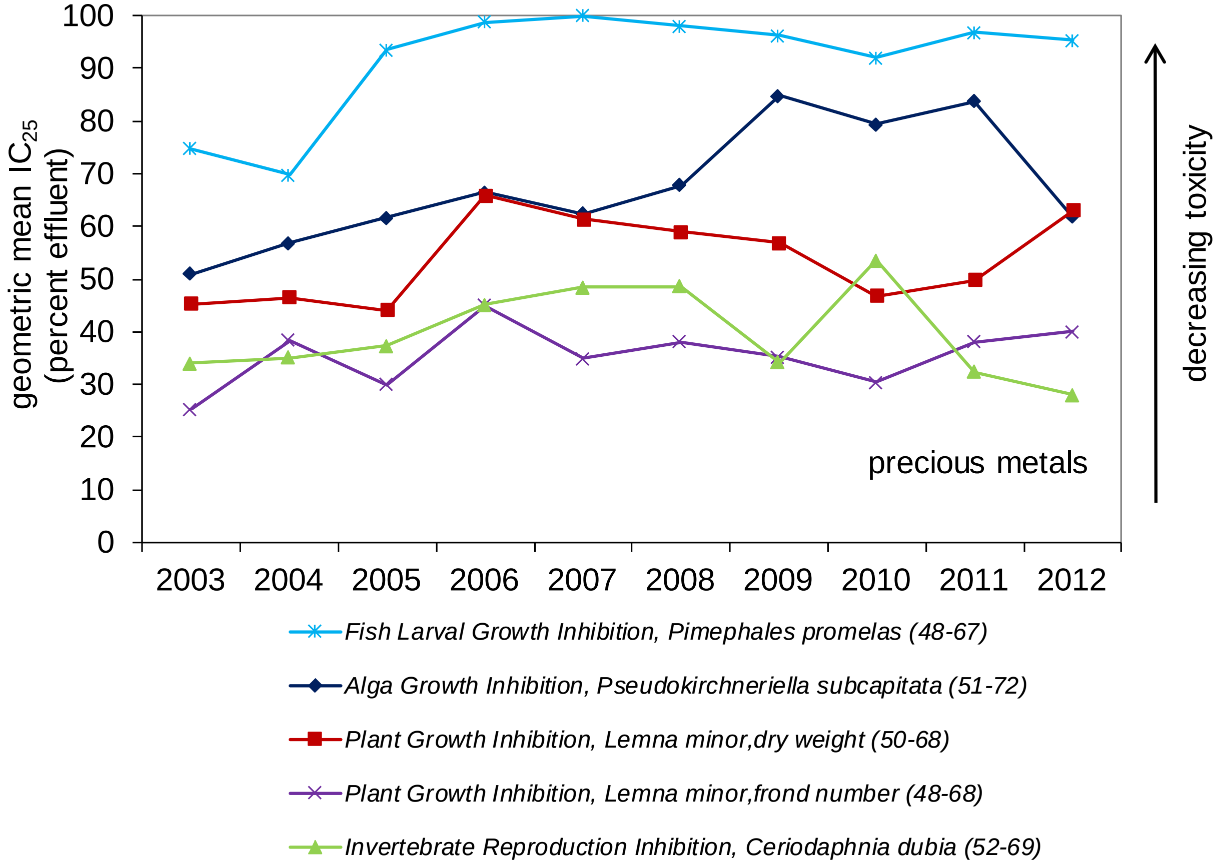


**Figure F1.** Geometric mean $IC_{25}$ (percent effluent on a volume basis) each year for each SLT test at precious metal mines

Note: Range in number of tests conducted per year in parentheses.

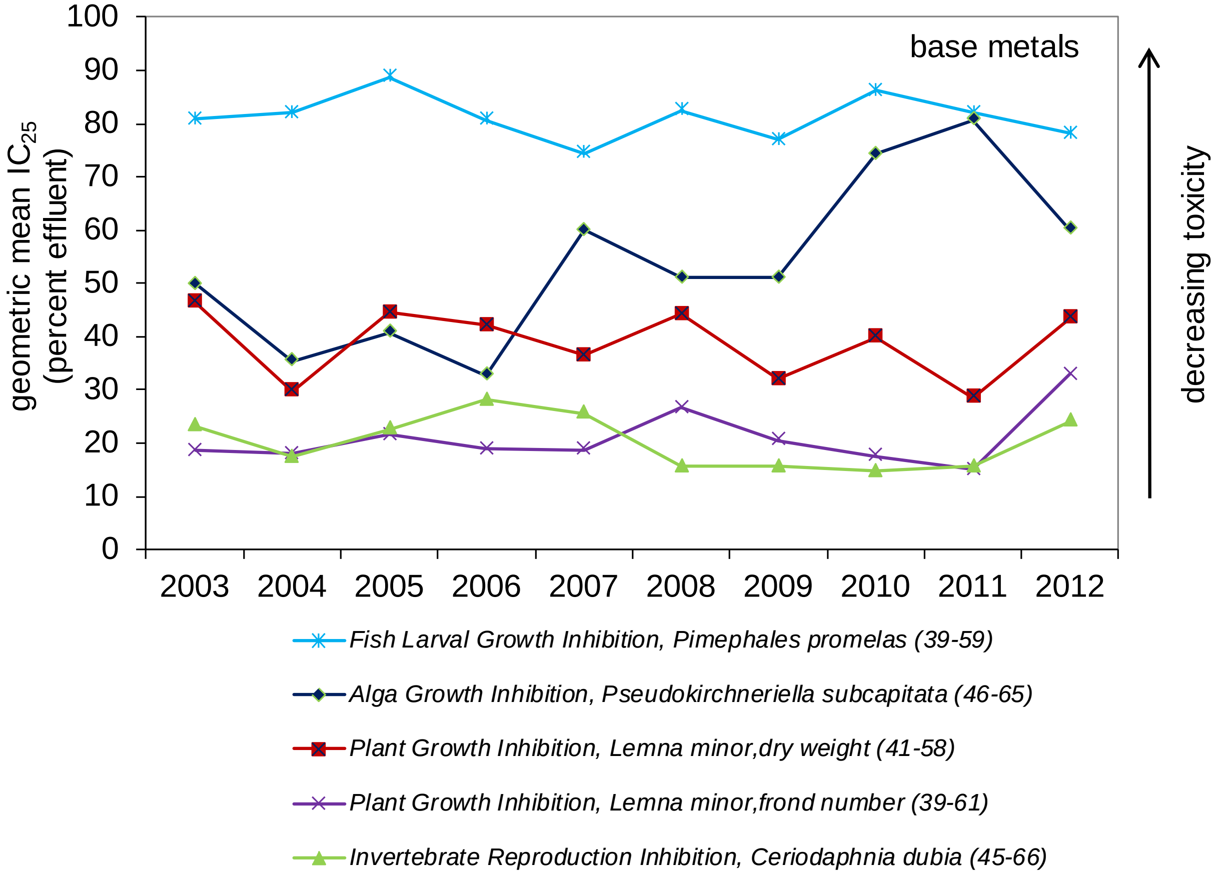


**Figure F2.** Geometric mean $IC_{25}$ (percent effluent on a volume basis) each year for each SLT test at base metal mines
Note: Range in number of tests conducted each year in parentheses.

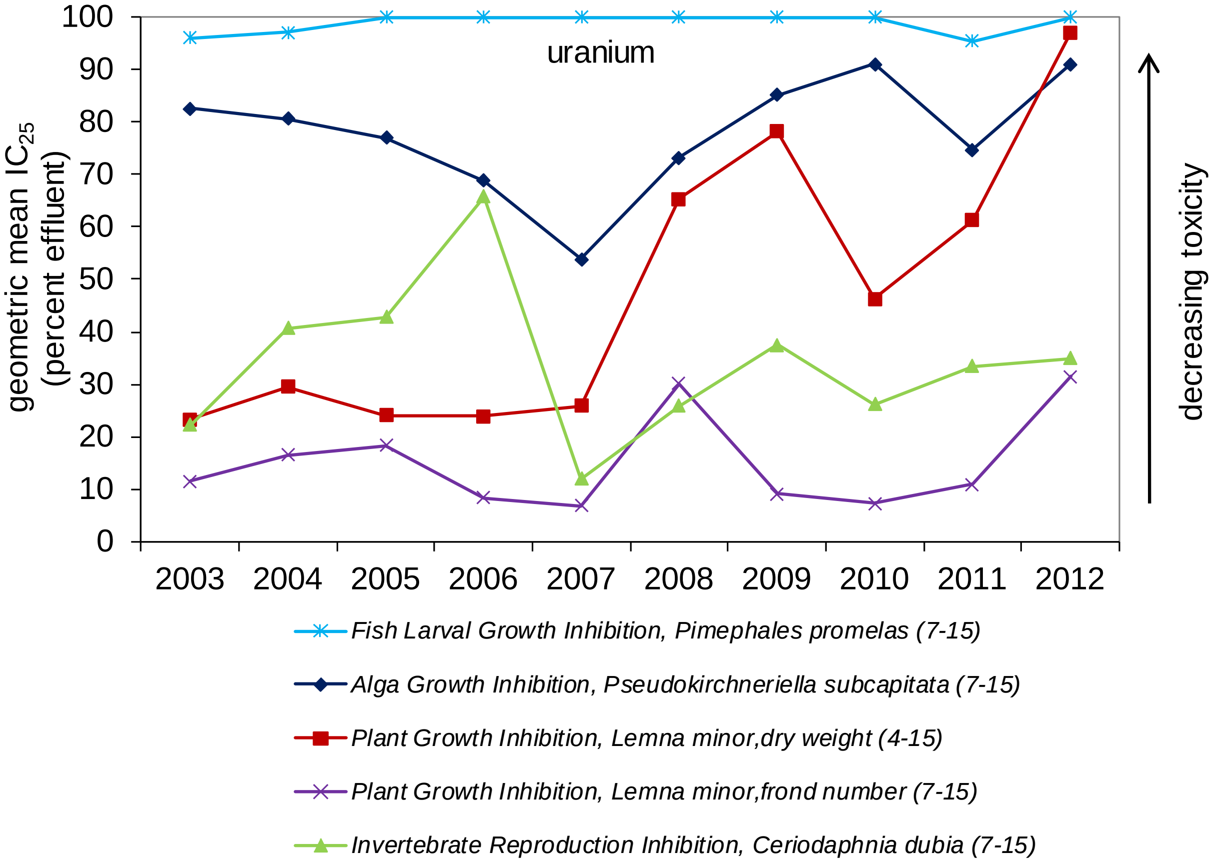


**Figure F3.** Geometric mean $IC_{25}$ (percent effluent on a volume basis) each year for each SLT test at uranium mines

Note: Range in number of tests conducted each year in parenthesis.

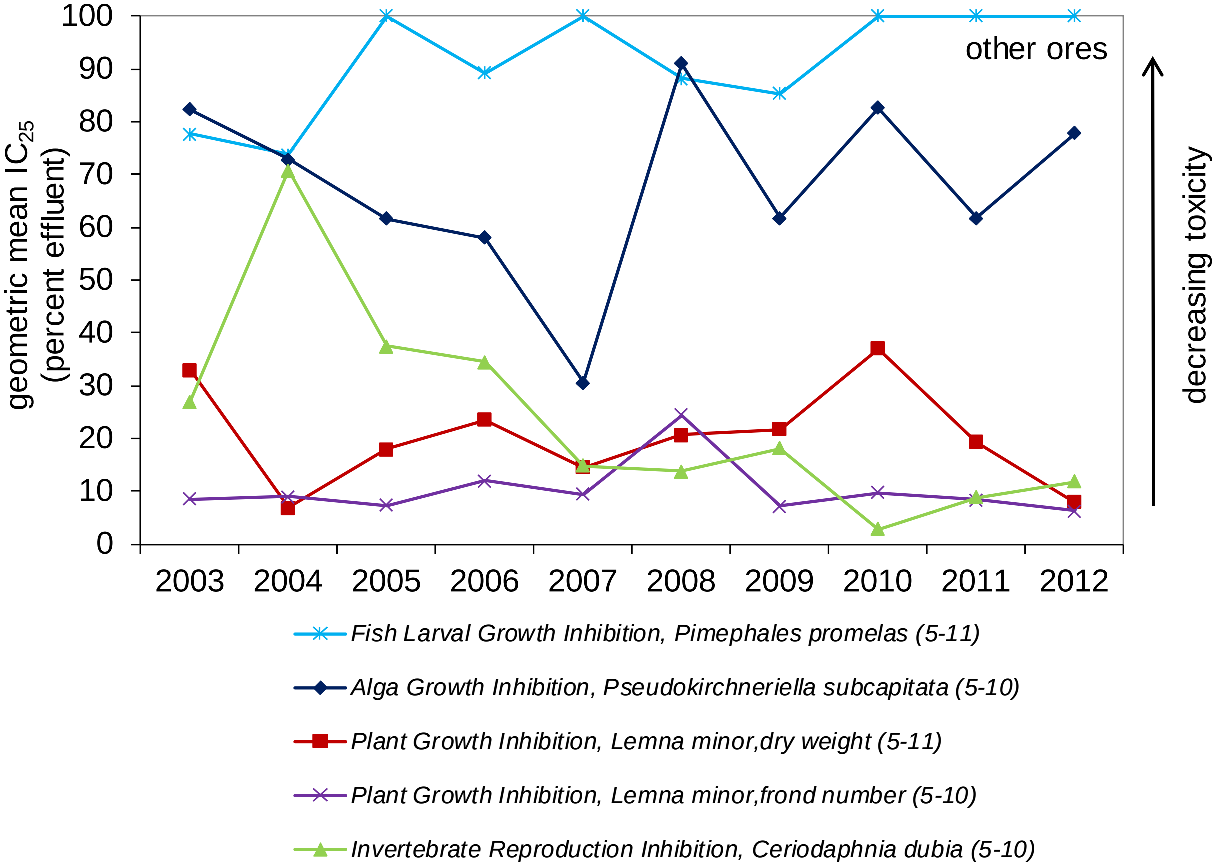


**Figure F4.** Geometric mean $IC_{25}$ (percent effluent on a volume basis) each year for each SLT test at mines with “other” ore types
Note: Range in number of tests conducted each year in parentheses.

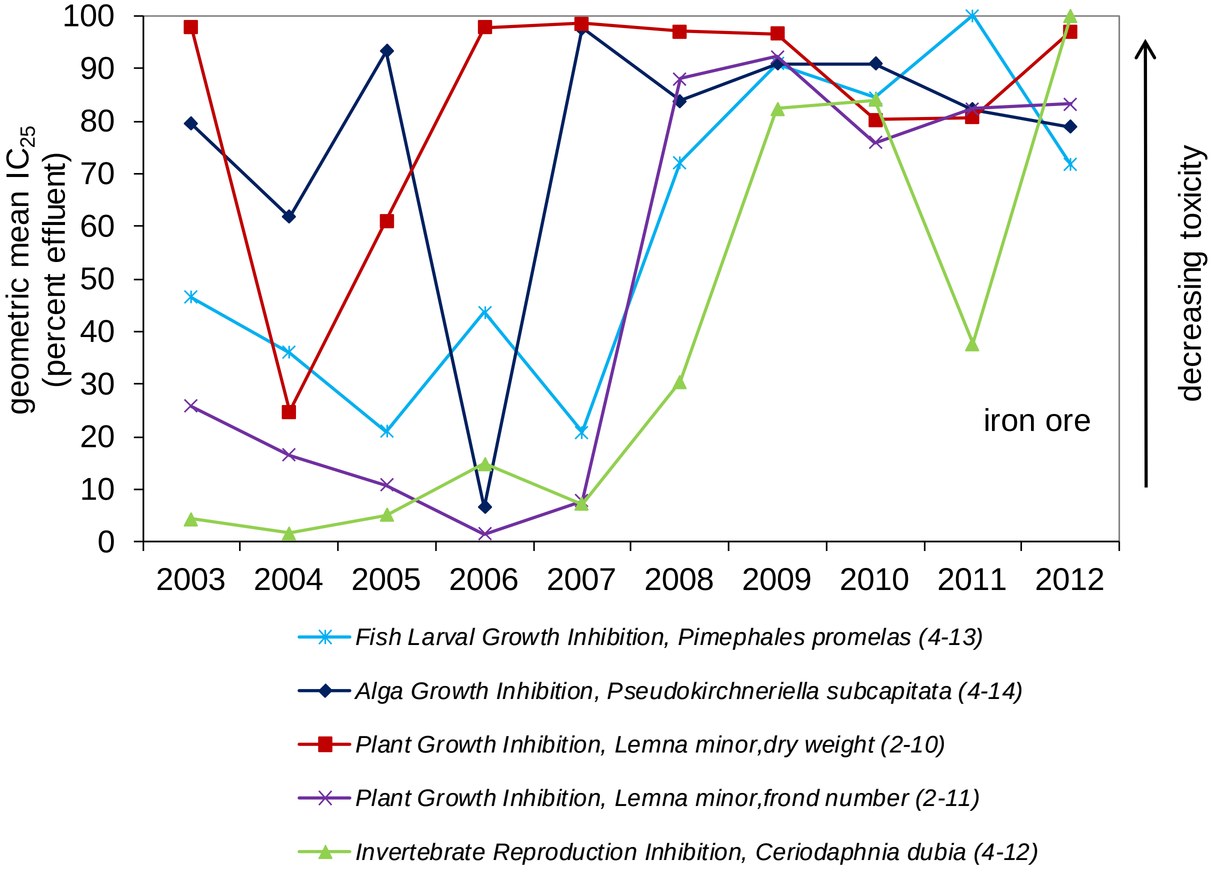


**Figure F5.** Geometric mean $IC_{25}$ (percent effluent on a volume basis) each year for each SLT test at iron ore mines

Note: Range in number of tests conducted each year in parentheses.

**Appendix G:** Annual Mean Concentrations of Effluent Characterization Data

**Table G1.** 2004 to 2012 annual mean concentrations of substances measured in the effluents of base metal mines from FDPs associated with biological monitoring studies and all other FDPs

| Year | Type of FDP | n | Hardness mg/L | Alkalinity mg/L | Aluminum mg/L | Cadmium mg/L | Iron mg/L | Mercury mg/L | Molybdenum mg/L | Ammonia mg/L | Nitrate mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2004** | *biological FDPs* | 33 | 1100 | 70 | 0.155 | 0.00086 | 0.219 | 0.00018 | 0.146 | 3.03 | 23.16 |
| | *other FDPs* | 11 | 681 | 105 | 0.140 | 0.00215 | 0.418 | 0.00002 | 2.323 | 0.26 | 3.46 |
| **2005** | *biological FDPs* | 35 | 995 | 59 | 0.180 | 0.00104 | 0.331 | 0.00025 | 0.184 | 1.51 | 6.94 |
| | *other FDPs* | 18 | 603 | 106 | 0.224 | 0.00903 | 0.594 | 0.00090 | 1.721 | 1.79 | 4.52 |
| **2006** | *biological FDPs* | 35 | 912 | 70 | 1.178 | 0.15115 | 3.654 | 0.00547 | 0.220 | 1.47 | 5.30 |
| | *other FDPs* | 20 | 510 | 82 | 0.438 | 0.00134 | 0.864 | 0.00001 | 1.152 | 0.47 | 2.14 |
| **2007** | *biological FDPs* | 37 | 918 | 75 | 0.396 | 0.00074 | 0.419 | 0.00253 | 0.207 | 1.93 | 6.00 |
| | *other FDPs* | 17 | 572 | 104 | 0.242 | 0.01579 | 1.384 | 0.00002 | 1.819 | 0.20 | 1.95 |
| **2008** | *biological FDPs* | 45 | 863 | 95 | 0.504 | 0.00165 | 0.286 | 0.00006 | 0.267 | 2.36 | 7.43 |
| | *other FDPs* | 19 | 539 | 100 | 0.237 | 0.00147 | 0.376 | 0.00002 | 1.935 | 0.51 | 2.47 |
| **2009** | *biological FDPs* | 43 | 826 | 76 | 0.119 | 0.00092 | 0.265 | 0.00002 | 0.212 | 1.12 | 4.89 |
| | *other FDPs* | 20 | 518 | 98 | 0.150 | 0.00183 | 0.377 | 0.00003 | 2.094 | 0.22 | 1.83 |
| **2010** | *biological FDPs* | 43 | 920 | 79 | 0.096 | 0.00072 | 0.233 | 0.00002 | 0.211 | 1.35 | 4.24 |
| | *other FDPs* | 18 | 574 | 103 | 0.149 | 0.00288 | 0.279 | 0.00002 | 2.407 | 0.20 | 1.41 |
| **2011** | *biological FDPs* | 48 | 888 | 76 | 0.082 | 0.01145 | 0.456 | 0.00002 | 0.224 | 1.52 | 4.88 |
| | *other FDPs* | 25 | 615 | 131 | 1.249 | 0.00114 | 3.330 | 0.00001 | 1.854 | 0.17 | 1.70 |
| **2012** | *biological FDPs* | 51 | 891 | 75 | 0.333 | 0.14092 | 0.299 | 0.00002 | 0.141 | 1.18 | 4.50 |
| | *other FDPs* | 24 | 618 | 125 | 0.211 | 0.00079 | 0.330 | 0.00094 | 2.389 | 0.26 | 2.82 |

**Table G2.** 2004 to 2012 annual mean concentrations of substances measured in the effluents of iron ore mines from FDPs associated with biological monitoring studies and all other FDPs

| Year | Type of FDP | n | Hardness mg/L | Alkalinity mg/L | Aluminum mg/L | Cadmium mg/L | Iron mg/L | Mercury mg/L | Molybdenum mg/L | Ammonia mg/L | Nitrate mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2004** | *biological FDPs* | 3 | 556 | 45 | 4.720 | 0.00325 | 1044.891 | 0.00004 | 0.007 | 3.64 | 5.60 |
| | *other FDPs* | 10 | 226 | 42 | 0.970 | 0.00051 | 405.405 | 0.00004 | 0.004 | 0.46 | 1.67 |
| **2005** | *biological FDPs* | 3 | 2305 | 46 | 39.131 | 0.01181 | 2846.823 | 0.00009 | 0.010 | 2.35 | 4.07 |
| | *other FDPs* | 11 | 253 | 39 | 2.508 | 0.00139 | 332.712 | 0.00004 | 0.002 | 0.97 | 2.69 |
| **2006** | *biological FDPs* | 3 | 1521 | 43 | 27.941 | 0.00886 | 1635.333 | 0.00006 | 0.010 | 2.85 | 5.22 |
| | *other FDPs* | 11 | 229 | 41 | 2.073 | 0.00122 | 214.710 | 0.00005 | 0.002 | 1.34 | 3.24 |
| **2007** | *biological FDPs* | 3 | 503 | 37 | 9.158 | 0.00471 | 591.118 | 0.00336 | 0.004 | 3.15 | 6.04 |
| | *other FDPs* | 11 | 198 | 43 | 1.467 | 0.00138 | 129.370 | 0.00139 | 0.002 | 2.69 | 4.75 |
| **2008** | *biological FDPs* | 4 | 1092 | 38 | 25.794 | 0.00 | 1655.911 | 0.00027 | 0.010 | 2.89 | 5.34 |
| | *other FDPs* | 13 | 150 | 50 | 1.531 | 0.00031 | 102.672 | 0.00002 | 0.002 | 1.24 | 5.22 |
| **2009** | *biological FDPs* | 4 | 50 | 36 | 0.196 | 0.00023 | 0.586 | 0.00001 | 0.001 | 0.57 | 2.61 |
| | *other FDPs* | 10 | 80 | 47 | 0.443 | 0.00024 | 1.376 | 0.00001 | 0.001 | 1.73 | 6.27 |
| **2010** | *biological FDPs* | 5 | 48 | 32 | 0.116 | 0.00019 | 0.590 | 0.00003 | 0.001 | 0.39 | 2.60 |
| | *other FDPs* | 9 | 76 | 43 | 0.189 | 0.00020 | 1.539 | 0.00002 | 0.115 | 2.00 | 6.16 |
| **2011** | *biological FDPs* | 7 | 51 | 33 | 0.251 | 0.00014 | 1.446 | 0.00004 | 0.002 | 0.58 | 3.65 |
| | *other FDPs* | 7 | 87 | 47 | 0.324 | 0.00006 | 2.193 | 0.00001 | 0.001 | 1.50 | 6.28 |
| **2012** | *biological FDPs* | 6 | 66 | 39 | 0.087 | 0.00015 | 0.561 | 0.00001 | 0.002 | 0.77 | 4.98 |
| | *other FDPs* | 7 | 89 | 50 | 0.218 | 0.00004 | 0.889 | 0.00001 | 0.001 | 2.02 | 6.80 |

**Table G3.** 2004 to 2012 annual mean concentrations of substances measured in the effluents of precious metal mines from FDPs associated with biological monitoring studies FDPs and all other FDPs

| Year | Type of FDP | n | Hardness mg/L | Alkalinity mg/L | Aluminum mg/L | Cadmium mg/L | Iron mg/L | Mercury mg/L | Molybdenum mg/L | Ammonia mg/L | Nitrate mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2004** | *biological FDPs* | 25 | 792 | 81 | 0.158 | 0.00065 | 0.322 | 0.00005 | 0.052 | 5.48 | 9.65 |
| | *other FDPs* | 11 | 157 | 65 | 0.065 | 0.00041 | 1.763 | 0.00006 | 0.009 | 2.74 | 2.75 |
| **2005** | *biological FDPs* | 28 | 681 | 75 | 0.221 | 0.00041 | 0.318 | 0.00024 | 0.045 | 5.57 | 12.58 |
| | *other FDPs* | 9 | 187 | 61 | 0.072 | 0.00019 | 1.942 | 0.00015 | 0.009 | 1.69 | 3.01 |
| **2006** | *biological FDPs* | 36 | 557 | 87 | 0.301 | 0.00041 | 0.279 | 0.00005 | 0.050 | 3.77 | 10.78 |
| | *other FDPs* | 13 | 267 | 71 | 0.162 | 0.00022 | 1.091 | 0.00005 | 0.054 | 0.92 | 6.59 |
| **2007** | *biological FDPs* | 35 | 549 | 95 | 0.177 | 0.00033 | 0.281 | 0.00005 | 0.036 | 3.71 | 9.77 |
| | *other FDPs* | 19 | 370 | 74 | 0.650 | 0.00014 | 1.075 | 0.00004 | 0.069 | 3.39 | 11.01 |
| **2008** | *biological FDPs* | 42 | 547 | 88 | 0.787 | 0.00054 | 2.311 | 0.00025 | 0.041 | 3.97 | 12.72 |
| | *other FDPs* | 15 | 329 | 66 | 0.138 | 0.00019 | 1.660 | 0.00003 | 0.039 | 4.27 | 13.89 |
| **2009** | *biological FDPs* | 40 | 480 | 92 | 0.186 | 0.00026 | 0.439 | 0.00016 | 0.039 | 3.08 | 13.51 |
| | *other FDPs* | 14 | 324 | 74 | 0.089 | 0.00022 | 1.459 | 0.00003 | 0.055 | 2.04 | 6.86 |
| **2010** | *biological FDPs* | 41 | 531 | 91 | 0.137 | 0.00028 | 0.272 | 0.00008 | 0.041 | 3.36 | 13.27 |
| | *other FDPs* | 15 | 428 | 86 | 0.075 | 0.00022 | 1.817 | 0.00002 | 0.071 | 2.55 | 6.21 |
| **2011** | *biological FDPs* | 42 | 497 | 98 | 0.451 | 0.00014 | 0.329 | 0.00008 | 0.052 | 3.06 | 14.48 |
| | *other FDPs* | 9 | 448 | 68 | 0.073 | 0.00011 | 0.122 | 0.00004 | 0.084 | 2.75 | 7.19 |
| **2012** | *biological FDPs* | 47 | 522 | 95 | 0.287 | 0.00013 | 0.421 | 0.00014 | 0.050 | 4.13 | 19.55 |
| | *other FDPs* | 8 | 455 | 78 | 0.270 | 0.00012 | 0.232 | 0.00002 | 0.104 | 3.07 | 10.39 |

**Table G4.** 2004 to 2012 annual mean concentrations of substances measured in the effluents of uranium mines from FDPs associated with biological monitoring studies FDPs and all other FDPs

| Year | Type of FDP | n | Hardness mg/L | Alkalinity mg/L | Aluminum mg/L | Cadmium mg/L | Iron mg/L | Mercury mg/L | Molybdenum mg/L | Ammonia mg/L | Nitrate mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2004** | *biological FDPs* | 6 | 741 | 21 | 0.065 | 0.00050 | 0.325 | 0.00106 | 1.498 | 6.50 | 3.77 |
| | *other FDPs* | 2 | 27 | 12 | 0.003 | 0.00050 | 0.083 | 0.00003 | 0.003 | 0.06 | 1.51 |
| **2005** | *biological FDPs* | 7 | 815 | 20 | 0.052 | 0.00052 | 0.232 | 0.00057 | 1.707 | 7.66 | 8.55 |
| | *other FDPs* | 2 | 30 | 14 | 0.003 | 0.00050 | 0.041 | 0.00003 | 0.002 | 0.06 | 1.85 |
| **2006** | *biological FDPs* | 6 | 938 | 15 | 0.148 | 0.00050 | 0.209 | 0.00003 | 1.212 | 7.79 | 19.37 |
| | *other FDPs* | 1 | 1 | 9 | 0.003 | 0.00063 | 0.004 | 0.00003 | 0.004 | 0.09 | 0.33 |
| **2007** | *biological FDPs* | 6 | 925 | 19 | 0.193 | 0.00041 | 0.326 | 0.00003 | 1.011 | 7.03 | 17.49 |
| | *other FDPs* | 1 | 2 | 7 | 0.001 | 0.00005 | 0.026 | 0.00003 | 0.006 | 0.04 | 1.78 |
| **2008** | *biological FDPs* | 6 | 915 | 17 | 0.111 | 0.00052 | 0.210 | 0.00003 | 0.898 | 6.70 | 26.80 |
| | *other FDPs* | 1 | 2 | 5 | 0.000 | 0.00005 | 0.009 | 0.00003 | 0.000 | 0.04 | 2.40 |
| **2009** | *biological FDPs* | 6 | 920 | 19 | 0.081 | 0.00036 | 0.225 | 0.00002 | 0.742 | 5.57 | 24.42 |
| | *other FDPs* | 2 | 37 | 13 | 0.004 | 0.00004 | 0.117 | 0.00002 | 0.003 | 0.05 | 3.11 |
| **2010** | *biological FDPs* | 5 | 1094 | 17 | 0.098 | 0.00004 | 0.149 | 0.00001 | 0.305 | 5.03 | 15.45 |
| | *other FDPs* | 2 | 40 | 12 | 0.003 | 0.00001 | 0.088 | 0.00001 | 0.003 | 0.05 | 4.66 |
| **2011** | *biological FDPs* | 5 | 1010 | 16 | 0.124 | 0.00001 | 0.242 | 0.00065 | 0.128 | 4.58 | 20.28 |
| | *other FDPs* | 3 | 120 | 11 | 0.003 | 0.00001 | 0.075 | 0.00001 | 0.008 | 0.02 | 21.98 |
| **2012** | *biological FDPs* | 5 | 978 | 18 | 0.115 | 0.00002 | 0.142 | 0.00002 | 0.169 | 5.98 | 21.08 |
| | *other FDPs* | 3 | 94 | 11 | 0.002 | 0.00001 | 0.052 | 0.00001 | 0.008 | 0.04 | 21.87 |

**Table G5.** 2004 to 2012 annual mean concentrations of substances measured in the effluents of “other” types of mines from FDPs associated with biological monitoring studies and all other FDPs

| Year | Type of FDP | n | Hardness mg/L | Alkalinity mg/L | Aluminum mg/L | Cadmium mg/L | Iron mg/L | Mercury mg/L | Molybdenum mg/L | Ammonia mg/L | Nitrate mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2004** | *biological FDPs* | 2 | 208 | 81 | 0.063 | 0.00005 | 0.228 | 0.00008 | 0.013 | 7.25 | 3.78 |
| | *other FDPs* | 1 | 157 | 216 | 0.050 | 0.00001 | 0.933 | 0.00010 | 0.005 | 0.15 | 0.06 |
| **2005** | *biological FDPs* | 2 | 208 | 68 | 0.092 | 0.00007 | 0.082 | 0.00004 | 0.013 | 6.79 | 4.07 |
| | *other FDPs* | 0 | - | - | - | - | - | - | - | - | - |
| **2006** | *biological FDPs* | 2 | 233 | 101 | 0.053 | 0.00005 | 0.186 | 0.00004 | 0.012 | 7.96 | 3.64 |
| | *other FDPs* | 0 | - | - | - | - | - | - | - | - | - |
| **2007** | *biological FDPs* | 2 | 249 | 97 | 0.097 | 0.00007 | 0.273 | 0.00008 | 0.014 | 6.21 | 3.29 |
| | *other FDPs* | 0 | - | - | - | - | - | - | - | - | - |
| **2008** | *biological FDPs* | 2 | 246 | 75 | 0.030 | 0.00003 | 0.113 | 0.00003 | 0.013 | 6.29 | 4.01 |
| | *other FDPs* | 0 | - | - | - | - | - | - | - | - | - |
| **2009** | *biological FDPs* | 2 | 261 | 73 | 0.020 | 0.00004 | 0.158 | 0.00003 | 0.013 | 12.38 | 5.55 |
| | *other FDPs* | 0 | - | - | - | - | - | - | - | - | - |
| **2010** | *biological FDPs* | 2 | 328 | 90 | 0.027 | 0.00003 | 0.148 | 0.00002 | 0.010 | 8.20 | 5.18 |
| | *other FDPs* | 0 | - | - | - | - | - | - | - | - | - |
| **2011** | *biological FDPs* | 2 | 345 | 91 | 0.043 | 0.00003 | 0.169 | 0.00003 | 0.009 | 10.58 | 5.81 |
| | *other FDPs* | 0 | - | - | - | - | - | - | - | - | - |
| **2012** | *biological FDPs* | 2 | 317 | 77 | 0.038 | 0.00004 | 0.122 | 0.00002 | 0.010 | 10.09 | 6.61 |
| | *other FDPs* | 0 | - | - | - | - | - | - | - | - | - |

**Appendix H:** Mine-by-Mine Summary of Investigation Studies

**Table H1.** Mine-by-mine summary of investigation of cause (IOC) and magnitude and geographic extent (M&E) studies

na - assessment of far-field effects was not available because the M&E assessment was based on existing data or was not possible due to confounding factors in the receiving environment.

[a] - ongoing IOC study (first 3-year study of two-part study completed)

| Mine code | Components with confirmed effects | Causes determined<br>As stated in Study Reports submitted to Environment and Climate Change Canada | M&E study results – at least 1 confirmed effect observed in far-field? |
|---|---|---|---|
| **Predominantly inhibitory effects (fish habitat and/or fish)** | | | |
| BM5, BM6, BM11 | fish habitat | Subtle effluent-related effect in 2 of 3 exposure areas; effluent-related effect not identified in 1 exposure area | na |
| BM10, BM27 | fish habitat and fish | Mine-related exposure to metals; most likely contaminants of concern are cadmium, copper, iron, selenium, and zinc[a] | Yes (fish habitat and fish) |
| BM14 | fish habitat | Elevated cadmium, selenium, and zinc in water and sediment from effluent discharge | Yes |
| BM19 | fish habitat | Multiple stressors from both historical impacts and current activities in watershed; non-point sources downstream from effluent discharge are main source of metal loadings | Yes |
| PM2, PM11 | fish habitat and fish | Effects on benthic community likely related to high metal concentrations in water and sediments; further study needed to determine relative importance of current mine effluent vs. historical mine waste[a] | Yes (fish) |

| Mine code | Components with confirmed effects | Causes determined<br>As stated in Study Reports submitted to Environment and Climate Change Canada | M&E study results – at least 1 confirmed effect observed in far-field? |
|---|---|---|---|
| PM14 | fish habitat and fish | Effects on fish and fish habitat may be related to nitrogen compounds in effluent[a] | na |
| PM25 | fish | Effects may be related to nutrient enrichment caused by nitrogen compounds and total suspended solids in effluent | na |
| PM29 | fish | Potential causes: elevated copper level in water, differences in fish hatch times between sampling areas | na |
| PM30 | fish | Potential causes: ammonia and nitrate in mine effluent, mine-related copper in sediments, and/or hydrocarbons in sediment | na |
| PM36 | fish habitat and fish | Effluent-induced meromixis due to high total dissolved solids causing low dissolved oxygen and low productivity in exposure area | yes (fish habitat) |
| U1 | fish habitat | Effects may be related to trace elements in sediment and/or water; weight-of-evidence approach did not identify a single exposure route (current mine effluent or sediment) as the primary pathway for contaminant exposure in the benthic community | yes |
| FeTi1 | fish habitat and fish | Benthic effects attributed to smothering of habitat with Fe-rich colloidal material; fish effects related to reduced food availability resulting from impacts to benthic community | yes (fish habitat and fish) |
| O3 | fish habitat and fish | Exposure to elevated chloride, salinity, total Suspended solids, ammonia and nitrate in effluent | no |

| Mine code | Components with confirmed effects | Causes determined<br>As stated in Study Reports submitted to Environment and Climate Change Canada | M&E study results – at least 1 confirmed effect observed in far-field? |
|---|---|---|---|
| **Predominantly inhibitory effects on fish habitat, mixed effects on fish** | | | |
| BM3 | fish habitat and fish | Benthic effects associated with ongoing impacts of historical streambed/floodplain sediment contamination on pH and metal concentrations; some effects may be related to elevated major ions, strontium, and thallium in mine effluent | yes (fish habitat) |
| BM4 | fish habitat and fish | Benthic effects likely caused by waterborne exposure to metals in effluent, most notably zinc; further study required to assess cause of fish effects; natural variability may be a more likely cause than metal exposure[a] | yes (fish) |
| **Predominantly inhibitory effects on fish, stimulatory effects on fish habitat** | | | |
| PM35 | fish habitat and fish | Potential causes: major ions, nutrient enrichment, trace metals, natural variability[a] | yes (fish habitat) |
| **Predominantly stimulatory effects (benthic invertebrates and/or fish)** | | | |
| BM1 | fish habitat and fish | No evidence that current effluent causes effects; fish effects indicative of natural variability between exposure and reference areas | yes (fish) |
| BM20 | fish habitat | Effects may be related to major ions (chloride, sulphate, sodium, calcium) in mine effluent and current or historical sediment contamination (nickel) | na |
| PM3 | fish | Major ions (chloride, sulphate) and/or nutrients (nitrate, ammonia) in mine effluent | na |

| Mine code | Components with confirmed effects | Causes determined<br>As stated in Study Reports submitted to Environment and Climate Change Canada | M&E study results – at least 1 confirmed effect observed in far-field? |
|---|---|---|---|
| U3 | fish habitat | Natural variability in habitat between sites; possible influence of natural or mine-related nutrient enrichment and mine-related contaminants | yes |
| U4 | fish | Elevated concentrations of major ions in mine effluent and slightly elevated water temperatures in exposure area may have contributed to stimulatory response | yes |
| U5 | fish habitat and fish | Benthic effects related to increased concentrations of major ions (calcium, sodium, potassium, sulphate, chlorine) in exposure area; fish effects most likely related to differences in habitat quality and prey availability (non-effluent related) | yes (fish habitat) |
| O4 | fish habitat | Nutrient enrichment (phosphorus) from mine effluent | yes |
| **Predominantly stimulatory effects on fish habitat, mixed effects on fish** | | | |
| PM1 | fish habitat and fish | No strong indication of eutrophication or toxic substances causing effects in exposure area | yes (fish habitat) |
| PM21 | fish habitat and fish | Effects likely caused by nitrate and ammonia in mine effluent | yes (fish habitat) |
| **Predominantly stimulatory effects on fish, mixed effects on fish habitat** | | | |
| PM28 | fish habitat and fish | Cause not yet determined; effects may be related to nutrient enrichment caused by nitrogen compounds in effluent[a] | no |
| **Similarity effect only for fish habitat, mixed effects on fish** | | | |

| Mine code | Components with confirmed effects | Causes determined<br>As stated in Study Reports submitted to Environment and Climate Change Canada | M&E study results – at least 1 confirmed effect observed in far-field? |
|---|---|---|---|
| U2 | fish habitat and fish | Combined influence of nutrients and major ions may be related to increased fish growth | yes (fish habitat) |
| FeTi2 | fish habitat and fish | Cause not yet determined; iron and nitrogen compounds identified as potential causes to be further investigated[a] | na |
| **Similarity effect only for fish habitat, no confirmed effects on fish** | | | |
| BM2 | fish habitat | Effects may be related to major ions (e.g., chloride, sulphate, sodium) and nitrogen in mine effluent, and trace metals (nickel) in mine effluent and sediments | na |
| BM18 | fish habitat | Phosphate in mine effluent | na |
| PM4 | fish habitat | Effect likely caused by mine activities, including elevated major ions in mine effluent and trace metals in sediment; some variation in benthic communities may be related to natural habitat differences | na |

Additional information can be obtained at:

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